CORNELL UNIVERSITY

OFFICIAL PUBLICATION

College of Engineering

THE SCHOOL OF CIVIL ENGINEERING

THE SIBLEY SCHOOL OF MECHANICAL ENGINEERING

THE SCHOOL OF ELECTRICAL ENGINEERING

THE SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING

THE DEPARTMENT OF ENGINEERING PHYSICS

AGRICULTURAL ENGINEERING

THE GRADUATE SCHOOL OF AERONAUTICAL ENGINEERING

1955-56

Contents

The Approach to an Engineering Career

IT IS important to the young man contemplating an engineering career to recognize that a great many factors will combine to shape his professional progress, and to determine upon the best means, in the relatively short time available to him for his academic preparation, toward the development of the fully rounded background necessary for success. The high degree of technical competence required of the engineer has tended to overshadow the extent to which he is called upon for application of his judgment and integrity to the affairs of the world about him. In fact, the increasing complexity of world affairs and the strong influence of technological progress on economic, social, and political development have brought a high percentage of engineering graduates to positions of leadership in industry, commerce, government, and other areas outside the technical sphere.

It is the responsibility of engineering education, therefore, to develop not only a strong technical background, but to stimulate each engineer toward a broad personal culture as well. It is equally a challenge to each young man preparing for this profession to derive from his collegiate experience all of the elements of practical learning and intellectual inspiration that will foster his growth as an engineer, a citizen, and a leader over the long span of his professional life and in the many directions it may take.

An engineering career has its roots in science and technology, but in its breadth it touches many areas of human activity. The purpose of Cornell engineering and of Cornell life is to create a balanced experience that will serve the engineer in the full range of his future progress. In his studies the Cornell engineer builds a broad foundation of fundamentals in the basic sciences, in basic engineering applications, and in modern technology, much of which is given substance in extensive laboratory practice. He follows a major branch of engineering, avoiding the limitations imposed on future development by narrow specialization—in fact, he studies fundamentals in the adjacent areas

of engineering in anticipation of a wide scope of future activities. This broad basic approach has enabled a considerable number of Cornell engineers to develop opportunities outside their original fields of study and experience and to gain distinction in complex enterprises requiring the coordination of many and varied activities.

The further development of this kind of background is supported by the inclusion of a solid core of liberal, general, and managerial studies throughout the period of his technical studies. By including the equivalent of a full year's work in these studies in the five years of engineering training, the young engineer achieves a broadened philosophy and understanding as a natural part of his professional background.

Formal academic work occupies a substantial part of each student's time; nevertheless, it is only a part. Beyond this are the opportunities of university life that form a distinctive influence in personal development and that should be a primary objective in the plan of each student for a collegiate experience of maximum effectiveness. We are particularly happy that the Cornell engineer can study and live in an atmosphere that is not only of strong engineering aspect but that is charged as well with the vitality of a university community dedicated to scholarship in the whole range of human endeavor. He carries with him, therefore, not only the components of his own learning, but also the intellectual stimulation of his association with the university community and the spiritual influence of the university's natural setting. Much of the Cornell tradition has been shaped of these factors; much of the purpose of Cornell engineering gains substance through their effect.

It is our aim to make available to the students who have shown the aptitude, character, and high determination for engineering study at Cornell all of the elements of knowledge, experience, and inspiration that will make for notable achievement in a long professional career.

S. C. HOLLISTER
Dean

The College of Engineering

ITS HISTORY AND ORGANIZATION

ENGINEERING has had an important place in the program of Cornell University from the beginning. The Federal Land Grant, or Morrill Act of 1862, which supplied a considerable proportion of the University's original endowment, specified that a leading object of the institution should be to teach "such branches of learning as are related to . . . the mechanic arts"; and this provision was in perfect accord with the ideals of the founder and of the first president. Both Ezra Cornell, the practical man of affairs who had amassed a fortune in the Western Union Telegraph Company, and Andrew D. White, the brilliant scholar and educator who had carefully analyzed contemporary higher education in America and in Europe, believed in the equal dignity of scientific and classical studies and determined to put the practical arts, such as engineering, on the same plane with the humanities. This program was considered revolutionary when announced at the University's opening in 1868. That it has since been generally adopted by American universities indicates the soundness of the basic Cornell idea that instruction in engineering should be given on a high professional level. The College of Engineering still adheres firmly to this policy.

Mechanical engineering and civil engineering have been strong divisions of the University since its foundation. The first was originally called the College of Mechanic Arts and later the Sibley College of Mechanical Engineering and Mechanic Arts, in recognition of munificent gifts by Hiram Sibley, founder of the Western Union Telegraph Company, and his son, Hiram W. Sibley. Civil engineering, originally a separate school in the College of Mathematics and Engineering, and later the College of Civil Engineering, has also retained its identity to the present day.

In 1883 Cornell opened courses in electrical engineering, among the first to be offered anywhere in America; and in 1919, when the Board of Trustees formed the present College of Engineering, the School of Electrical Engineering was established as one of the three component units, on a par with the Sibley School of Mechanical Engineering and the School of Civil Engineering. In 1946 the Graduate School of Aeronautical Engineering was established. Also in 1946 the Department of Engineering Physics was organized with a five-year curriculum leading

to the degree of Bachelor of Engineering Physics. In 1952 a professional curriculum in agricultural engineering was established as a joint program with the College of Agriculture. All undergraduate curricula have now been extended to five years in order to provide the necessary technical preparation and at the same time to include the very desirable training in nontechnical subjects.

The College of Engineering organized courses in chemical engineering in 1931; and seven years later the School of Chemical Engineering was established to supervise the curriculum which leads to the degree of Bachelor of Chemical Engineering. A course in metallurgical engineering has now been added, and the name of the school has been changed to the School of Chemical and Metallurgical Engineering.

Students in engineering use the several buildings which house the Sibley School of Mechanical Engineering and, in addition, Lincoln Hall, devoted to the School of Civil Engineering; Franklin Hall, containing most of the School of Electrical Engineering; Rand Hall, the gift of Mrs. Florence O. R. Lang, housing electrical laboratories; the Hydraulic Laboratory on Beebe Lake above Triphammer Falls; and Olin Hall of Chemical Engineering, which was given by Franklin W. Olin to provide for the School of Chemical and Metallurgical Engineering. In 1952 a new building for materials laboratories was dedicated. One section, for research and instruction in materials, is named Thurston Hall, after Robert T. Thurston, first director of Sibley and organizer of the first collegiate laboratory of materials. The other laboratory, for materials processing, bears the name Kimball Hall, after Dexter S. Kimball, former dean of the College of Engineering and pioneer of courses in industrial engineering. Another new building, Phillips Hall, is the gift of Ellis L. Phillips and will serve the School of Electrical Engineering. For various preparatory and elective courses, students also use the Baker Laboratory of Chemistry, given to the University in 1922 by George F. Baker, and Rockefeller Hall, erected by John D. Rockefeller for the Department of Physics, as well as other buildings of the College of Arts and Sciences.

Cornell engineers enjoy all the benefits and privileges of an outstanding university community. They associate continually, in fraternities and dormitories, in extracurricular activities, and in general University functions, with students of liberal arts, agriculture, law, veterinary medicine, architecture, and other subjects. Concerts by world-famous soloists and orchestras, lectures by renowned scholars in widely varying fields, dramatic productions, and art exhibits add to the cultural atmosphere in which Cornell engineers live as undergraduates.

These facts, in addition to the beauty of the campus and the surrounding Finger Lakes region and the consideration that Ithaca is a small city, removed from the distractions of a metropolitan area but easily accessible by railroad and highway, help to explain the composi-

tion of the student population, which each year includes students from every part of the United States and numerous foreign countries.

The College of Engineering now comprises the School of Civil Engineering, the Sibley School of Mechanical Engineering, the School of Electrical Engineering, the School of Chemical and Metallurgical Engineering, the Department of Engineering Physics, the Departments of Mechanics and Materials, and the Graduate School of Aeronautical Engineering. In combination with the College of Agriculture, a five-year course of study is offered in professional agricultural engineering (page 71). Graduate instruction in engineering is offered by the Engineering Division of the Graduate School of the University.

OBJECTIVES OF CORNELL ENGINEERING

The broad purpose of instruction—and of the many phases of student life at Cornell—is to provide the elements of learning and inspiration that foster leadership in professional and personal affairs. In the record of achievement of generations of Cornell engineers, the University has a trust to maintain a high standard of academic experience and to select those students whose abilities, character, and purpose show promise of continuing a tradition of leadership.

Since the engineer has need of a balanced background, combining strength in fundamental technical knowledge with broad understanding of human affairs and competence in human relations, the Cornell plan provides for full integration in a single five-year period of both areas of study. It holds to two major principles: (a) that preparation for the uncharted technological advances of the future can come only from a solid foundation in the fundamentals of science and engineering, and (b) that the total collegiate experience of the engineering student should be a stimulus to lifelong intellectual growth rather than a "package" of incidental knowledge.

In conformance with these principles, the Cornell program is shaped of four integral stems of learning: (1) basic science (mathematics, physics, chemistry); (2) applied engineering science (mechanics, properties of materials, thermodynamics, electrical theory, and similar subjects); (3) applied technology (structural design, hydraulics, machine design, industrial engineering, electronics, power, chemical operations, and many other subjects related to modern engineering practice); (4) general, managerial, and liberal studies (English, history, management, psychology, public speaking, economics, law, and such additional subjects in the several divisions of the University as the student may elect to pursue for well-rounded personal development).

Upon the foundation of basic science and applied engineering science is built the understanding of technological processes and the ability to derive new applications from fundamentals—an ability essential to future development.

In the applied technology stem, students follow the engineering applications pertaining to their major branch of engineering. Although modern practice, laboratory experience, and practical methods are followed, studies again are related to the basic principles involved in the applications so that the student will gain an instinct for creative development from fundamental facts.

The stem of general, managerial, and liberal studies occupies a minimum of 20 per cent of each student's program. Some of these studies are prescribed, and some can be elected, with the objective of expanding personal interests and abilities. These studies are carried throughout the full period of the student's attendance so that, combined with his experiences and associations in a university community of broad interests and activities, they form an integral and natural part of his personal culture and a stimulus to further intellectual development.

No small part of the Cornell engineer's cultural background comes from his living in a setting of inspirational natural beauty, in close association with students and scholars from all parts of the world with all ranges of interest—agriculture and the arts, medicine and law, history and social science, as well as the physical sciences and technology.

The Cornell program includes both the more intensive technical training and the core of liberal experience essential to the long-range requirements of a full professional career. Its design avoids the necessity for narrow specialization, or for restriction of basic areas of study, and provides instead for a balanced background leading to broad technical competence, to a comprehension of the economic, social, and political forces with which engineers must deal, and to competence in the techniques of management and human relations.

Each entering undergraduate student selects the division of major study he expects to follow (chemical, civil, electrical, mechanical, metallurgical engineering, engineering physics). Aeronautical engineering can be followed as a graduate program upon completion of any of the undergraduate engineering programs or of a satisfactory major program in mathematics or physics. Similarly, graduate study in the respective areas of engineering can be undertaken by qualified students who show aptitude for advanced study in their undergraduate careers.

Since a primary purpose of Cornell engineering is to build a broad base of fundamentals, all engineering students study common basic subjects for a substantial part of the first five terms. This has the incidental advantage of permitting some transfer to adjacent major areas after original enrollment without serious loss of time, but it is primarily intended to prepare Cornell engineers for the diverse channels of engineering practice and for the many areas in which the activities of specific fields overlap.

Both in basic studies and in the study of technical processes and applications, laboratory practice, large-scale demonstrations, and field ex-

perience are used extensively. Students are expected to acquire considerable aptitude in integrating their various studies and experiences for the solution of practical engineering problems in their later courses.

The College is engaged in an extensive program of engineering research which is being carried out by members of the Faculty and their assistants. Although most of these projects are not directly associated with undergraduate activities, they create a stimulating atmosphere for academic work and provide a firsthand opportunity for all students to observe the ingenious application of basic principles to the extension of engineering frontiers.

In all, the objectives of Cornell engineering are achieved through the mutual determination of the student and the College to develop in the five-year period of his academic life the technical background and the personal culture that will support continuing growth over the full span of his professional career.

THE INDUSTRIAL COOPERATIVE PROGRAM

During the fourth term of the regular curriculum students in electrical and mechanical engineering who are in good standing may apply for admission to the Industrial Cooperative Program.

The Cooperative Program provides three work periods of term length (about 16 weeks each) in one of the following industries operating the plan with the University: American Gas and Electric Service Corporation, Air Reduction Company, Cornell Aeronautical Laboratory, General Electric Company, Philco Corporation, and Procter and Gamble.

By utilizing the three summer periods after the fourth term (normally vacation periods), Cooperative students are enabled to complete all the academic work regularly required for the Bachelor's degree and can graduate with their regular classes. The schedule is as follows after Term 4:

Period	*Term*	*Term*	*Term*
Summer	5	Industry	8
Fall	Industry	7	9
Spring	6	Industry	10

It is to be noted that the Cooperative student remains with his regular classmates during all terms on campus except the fifth and eighth, which he takes in the summer. The Cooperative Program therefore is not an accelerated program and involves a minimum of departure from the regular program.

Although the student is on the industry payroll during the work periods, the function of the plan is educational rather than to provide part-time employment. The work in industry is coordinated with the student's studies so far as practicable and provides an invaluable oppor-

tunity for him to direct his study interests on campus toward the realities of his future environment. Supervision is provided for each student, both from campus and industry, to ensure his obtaining optimum benefit from the Program. Many students have found this a profound influence on their objectives and on their progress both before and after graduation.

Applications for the Cooperative Program are accepted in the fourth term only. Applicants are subject to approval both by the College and by one of the cooperating industries. Admission to the plan involves no obligation on the part of either the student or the industry with regard to future employment.

COMBINED PROGRAMS IN LAW, BUSINESS AND PUBLIC ADMINISTRATION, AND CITY AND REGIONAL PLANNING

During the fourth year of the regular curriculum students in good standing in some divisions of the College of Engineering may apply for admission to special programs which will permit the completion of requirements for both the appropriate Bachelor's degree in engineering and one of the advanced or graduate degrees in law, business and public administration, or city and regional planning, in one year less than the normal period.

Ordinarily such a combined program, leading to two degrees, would constitute an eight-year course of study in the case of law and seven years in the case of business and public administration or city and regional planning. By choosing as electives courses acceptable to the other schools or colleges and by being permitted to count certain other courses as meeting requirements in both areas, students will be able to acquire the two degrees in the shortened period.

Arrangements for one or more such combined programs of study are possible for selected students in chemical, civil, electrical, and metallurgical engineering. Applications will be accepted at any time prior to the fifth year, but, for maximum flexibility and ease of program planning, the choice should be made as early as possible. Applications must be approved by both participating schools or colleges in any instance.

UNDERGRADUATE STUDIES IN AERONAUTICAL ENGINEERING

Applicants interested in the field of aeronautical engineering should apply for admission to the School of Mechanical Engineering, the School of Electrical Engineering, or the Department of Engineering Physics. In the regular five-year programs of these Schools they will obtain the fundamental scientific and humanistic courses that an aeronautical engineer must have; in addition, they may elect aeronautical

engineering courses in the Graduate School of Aeronautical Engineering during their fourth and fifth years (provided that their scholastic record at that time is adequate). They can also carry out Senior Projects in the aeronautical field, under the direction of staff members of the School of Aeronautical Engineering. By planning their programs in this way, these students obtain an unusually sound and well-rounded aeronautical engineering education, combining the broad engineering training of Cornell's five-year undergraduate curricula with specialized aeronautical studies of the type usually reserved for graduate students.

Applicants should mention their interest in aeronautical engineering when they apply for admission. The Director of the Graduate School of Aeronautical Engineering will assist them in planning their fourth and fifth-year programs so as to take greatest advantage of the offerings of that School.

CHOICE OF CURRICULUM

Every applicant for admission is asked to designate the branch of engineering he wishes to study, namely, civil engineering, mechanical engineering, electrical engineering, chemical engineering, metallurgical engineering, or engineering physics. Each branch has its own curriculum which carries its own professional degree.

The first year of study is essentially the same for all branches and includes mathematics, physics, chemistry, English, and appropriate courses in descriptive geometry or drafting. This similarity of the curricula in the freshman year makes it possible for students to transfer from one division to another of the College without great hindrance when for one reason or another a change of objective is desirable. Thus, no applicant in his first year need feel that by committing himself to a particular branch of engineering education he has made an irrevocable decision.

After the second year, as the several curricula begin to diversify, transfer within the College of Engineering is somewhat more difficult and in a few instances may necessitate an additional term or more of study.

Applications for transfer should be made to the Director of the prospective school during the term preceding the one in which the student wishes to change his course, and students should realize that the earlier such transfers are made the fewer will be the resulting complications of curricular adjustment.

DEGREES OFFERED

Cornell University confers the following degrees on the successful completion of undergraduate courses of study in the College of Engineering: Bachelor of Civil Engineering (B.C.E.); Bachelor of Mechan-

ical Engineering (B.M.E.); Bachelor of Electrical Engineering (B.E.E.); Bachelor of Chemical Engineering (B.Ch.E.); Bachelor of Metallurgical Engineering (B.Met.E.); Bachelor of Engineering Physics (B.Eng.Phys.); Bachelor of Agricultural Engineering (B.Agr.E.).

The advanced degrees of Master of Science (M.S.) and Doctor of Philosophy (Ph.D.) are granted by the University on the recommendation of the Faculty of the Graduate School.

The degree of Master of Aeronautical Engineering (M.Aero.E.) is granted on the recommendation of the Faculty of the Graduate School of Aeronautical Engineering.

REQUIREMENTS FOR GRADUATION

Baccalaureate degrees are conferred on candidates who have fulfilled the following requirements:

1. The candidate must have been in residence and registered in the College of Engineering for the last two terms and must have satisfied the University requirements in military training and physical education and in the payment of tuition and fees.

2. He must have completed to the satisfaction of the Faculty of the College of Engineering all the subjects and the elective hours prescribed in the course of study as outlined by that Faculty.

3. A student who transfers to the College of Engineering, after having spent one or more terms in another college of Cornell University or elsewhere, must conform to the requirements of the class with which he graduates.

4. Each student in the first term of the freshman year in the College of Engineering must attend regularly the lectures in orientation for students in engineering.

Requirements Changeable

The College of Engineering reserves the right to modify its curricula and specific courses of instruction, to alter the requirements for admission or for graduation, and to change the degrees to be awarded, and such changes are applicable to either prospective or matriculated students at any such time as the college may determine.

UNIVERSITY REQUIREMENTS

MILITARY TRAINING . . . All physically qualified undergraduate men who are American citizens must take military training during their first four terms. Enrollment in the basic course of military science and tactics or air science and tactics, or in the first two years of naval science, satisfies this requirement. Students transferring to Cornell from other institutions are exempt from part or all of the requirement, according

to the number of terms of residence in college before transfer, and service in the armed forces in World War II also satisfies the military training obligation. Entering students who have had ROTC training in secondary or military schools are requested to bring DD Form 68—Student's Record for presentation to the Military Department at the time of registration (see also page 122 of this Announcement).

PHYSICAL EDUCATION . . . All undergraduate students must pursue four terms of work, three hours a week, in physical education. Ordinarily, this requirement must be completed in the first two years of residence; postponements are to be allowed only by consent of the University Faculty Committee on Requirements for Graduation.

Exemption from this requirement may be made by the committee designated above, when it is recommended by the medical office or when unusual conditions of age, residence, or outside responsibilities require it.

For students entering with advanced standing, the number of terms of physical education required is to be reduced by the number of terms which the student has satisfactorily completed (whether or not physical education was included in his program) in a college of recognized standing.

GRADUATE STUDIES

A graduate of this college or of other colleges of engineering may enter the Graduate School of Cornell University and pursue advanced work in engineering. Such a student may enter either as a candidate for a degree (M.S. or Ph.D.) or without candidacy for a degree, according to the character of his previous training. A prospective graduate student should consult the *Announcement of the Graduate School* and apply to the Dean of the Graduate School. Information concerning graduate scholarships and fellowships, including the John McMullen Graduate Scholarships, can be obtained either from the Dean of the Graduate School or from the Dean of the College of Engineering.

Prospective candidates for the degree of M.Aero.E. should apply directly to the Director of the Graduate School of Aeronautical Engineering.

ENGINEERING LIBRARY

This library maintains working collections in the fields which it serves. Each year the most important new books are added to its stacks, as well as current issues of engineering journals and transactions and proceedings of many learned societies.

The library of the Schools of Civil, Mechanical, and Electrical Engineering in Sibley Dome includes, in addition to the regular collection, the following collections and facilities: The Kuiching Memorial Li-

brary and the support of the Irving Porter Church Fund in Civil Engineering; the Diederichs Memorial Library in Mechanical and Electrical Engineering and the James F. Lincoln Arc Welding Foundation Library in Mechanical Engineering; and the Alexander Gray Memorial Library in Electrical Engineering.

The School of Chemical and Metallurgical Engineering in Olin Hall has an unusually complete library in chemistry, chemical engineering, and metallurgical engineering.

A complete library of collections in physics and applied physics with large reading rooms is maintained in Rockefeller Hall as the Physics Branch of the University Library.

STUDENT PERSONNEL SERVICES

STUDENT PERSONNEL OFFICE . . . The admission of new students, the administration of scholarships in the College of Engineering, and the placement of graduates are activities of the College which are coordinated in the Student Personnel Office. The Personnel Office, in addition to other facilities, is also available at all times to students who wish to discuss any question relating to their life in the College.

STUDENT COUNSELING . . . In general, the counseling of students rests with the Class Advisers to whom the students are assigned primarily for assistance in planning and scheduling their academic work. In each School of the College, students are referred to the chairman of the scholarship committee when in financial need and to a placement adviser for assistance in vocational choice and postgraduate employment. Also, the students are free to consult with the Dean, Directors, department heads, and instructors not only on matters pertinent to their education and future plans, but also on personal matters. In addition, the University's Dean of Men and Dean of Women and their staffs may be consulted by students regarding their nonacademic problems. Both Deans have offices in Edmund Ezra Day Hall.

ASSISTANCE TO FOREIGN STUDENTS . . . The University maintains on its staff a Counselor to Foreign Students, whose duty is to look after the welfare of all students from other countries. He may be consulted on personal problems, social questions, or any other matter in which he may be helpful. His office is in Edmund Ezra Day Hall. It is suggested that all foreign students write him before coming to Ithaca or call on him immediately upon arrival. He will be glad to help them find suitable living quarters, either at the Cosmopolitan Club or elsewhere, and introduce them to other University officials, members of the Faculty, and other students.

FRESHMAN ORIENTATION . . . A series of orientation lectures is given to students in the fall term of the freshman year in the College of

Engineering. The primary purpose of these lectures is to acquaint the student with the scope of each of the major fields of engineering and with the opportunities and the responsibilities of men in the engineering professions.

THE ENGINEERING COLLEGE COUNCIL

The Engineering College Council consists of the President of the University, the Dean of the College, and a group of distinguished engineers, usually alumni, approved by the Board of Trustees of the University. The duties of the Council are to become thoroughly acquainted with the affairs of the College, to advise the administration and the Board of Trustees with regard to policies and programs designed to increase the efficiency of the established operations, to add to the available resources, to improve public and alumni relations, and in any other way to strengthen the College's work.

MISCELLANEOUS INFORMATION

DEAN'S HONOR LIST . . . Students of the College of Engineering whose weighted average in their studies is 85 per cent or better are included annually in an Honor List compiled for the Dean. The honor students comprise approximately the highest tenth of all the students enrolled in the college.

STUDENT ACTIVITIES . . . Students of the College of Engineering find many opportunities for engaging in wholesome activities outside their regular duties, and even outside the College, in company with other members of the University community. Within the College some find congenial occupation in helping to carry on the student branches of the national engineering societies, in conducting *The Cornell Engineer,* or in membership in national or local honor societies, which include Tau Beta Pi, Phi Kappa Phi, Sigma Xi, Pi Tau Sigma, Chi Epsilon, Rod and Bob, Pyramid, Atmos, Kappa Tau Chi, and Eta Kappa Nu. In the University at large there are student activities of all sorts—musical, dramatic, journalistic, social, and athletic.

ENGINEERING SOCIETIES . . . The College of Engineering is closely associated with the local sections of the American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Electrical Engineers, Society of Automotive Engineers, and Institute of Radio Engineers, many of the meetings of which are held on the campus and are participated in by the members of the College. The College also maintains active student branches of these national societies as well as of the American Institute of Chemical Engineers and the Institute of Aeronautical Sciences. The Cornell Metallurgical So-

ciety was formed in 1949 and is an affiliate of the American Institute of Mining and Metallurgical Engineers. Students in the Department of Engineering Physics formed in 1948 the Cornell Society of Engineering Physics. The meetings of such societies afford opportunities for addresses by engineers of eminence, for the presentation of papers by students, for discussion, or for contests in public speaking on engineering subjects. The School of Mechanical Engineering gives elective credit hours for activity in the student branches of the A.S.M.E.

The Cornell Engineer, a technical journal published monthly throughout the academic year, is managed and edited by undergraduates in the College of Engineering.

ADMISSION

METHOD OF APPLICATION AND REQUIREMENTS FOR ADMISSION . . . All correspondence concerning admission to the College of Engineering should be addressed to the Director of Admissions, Cornell University, Ithaca, New York, who will forward the necessary application blanks on request.

Detailed information concerning the requirements for admission and methods of procedure are outlined in the University's *General Information Announcement,* which every candidate for admission should read carefully and which can be obtained by application to Cornell University Official Publication, Edmund Ezra Day Hall, Ithaca.

Entrance subjects must include English (four units), elementary and intermediate algebra (two units), plane geometry (one unit), and trigonometry (one-half unit). A foreign language (two units) *or* history (two units); advanced algebra (one-half unit) *or* solid geometry (one-half unit); and chemistry (one unit) *or* physics (one unit) must also be offered. It is strongly recommended that at least three of the elective units offered to make up the balance of sixteen be in language or history. Applicants are also advised to offer advanced algebra rather than solid geometry, when a choice is possible. Candidates for admission to the School of Chemical and Metallurgical Engineering are required to have chemistry (one unit).

Each candidate for admission is required to take the Scholastic Aptitude Test of the College Entrance Examination Board and to request the Board to report the results to the Director of Admissions, Cornell University. Candidates are urged to take the test in January of their senior year.

SELECTIVE ADMISSION . . . The number of applicants admitted to the several schools of the College of Engineering is limited by the facilities available for adequate instruction. The committees on admissions in each of the Schools will exercise discretionary power in selecting

those to be admitted. Preference will be given to those candidates whose academic preparation and personal character indicate fitness to pursue with success the course of study to be undertaken, who show evidence of professional promise, and who complete the filing of their entrance credentials in ample time for the committee to give thorough consideration to their qualifications.

PAYMENTS TO THE UNIVERSITY

TUITION AND OTHER FEES . . . For information concerning tuition and other fees payable to the University, see the *General Information Announcement.*

HEALTH SERVICES AND MEDICAL CARE

These services are centered in the University Clinic or out-patient department and in the Cornell Infirmary or hospital. Students are entitled to unlimited visits at the Clinic; laboratory and X-ray examinations indicated for diagnosis and treatment; hospitalization in the Infirmary with medical care for a maximum of 14 days each term; and emergency surgical care. The cost for these services is included in the College and University general fee. For further details, including charges for special services, see the *General Information Announcement.*

FINANCIAL AID

Freshman Scholarships

General awards, open to entering students in *any* undergraduate division of the University, are described in the Announcement entitled *Financial Aids and Scholarships.* They include the Cornell National Scholarships, the LeFevre Scholarships, and the University Tuition Aid Scholarships. The scholarships described below are available *only* to students entering the College of Engineering.

Application blanks for all freshman scholarships may be obtained directly from the Scholarship Secretary, Office of Admissions, Edmund Ezra Day Hall.

ALFRED P. SLOAN NATIONAL SCHOLARSHIPS . . . (Established by the Alfred P. Sloan Foundation.) Open to men entering any division of the College of Engineering. Annual award varies from a prize scholarship of $200 to as much as $2,000, depending upon financial need. Tenure, not limited. Six scholarships awarded annually. Applicants will be selected on the basis of high character, sound personality, leadership potential, and scientific promise.

LOCKHEED NATIONAL ENGINEERING SCHOLARSHIP . . . (Es-

tablished by the Lockheed Leadership Fund.) Open to entering students in the College of Engineering. Annual award, tuition and fees and $500. Tenure, renewable for three additional years. One award each year to a student who is in a field of engineering applicable to the aircraft industry and whose total personal qualities can be expected upon graduation to offer a significant contribution to the aircraft industry.

MARTIN J. INSULL SCHOLARSHIP . . . (Gift of Mrs. Virginia Insull, his wife.) Open to men, only, entering the College of Engineering. Annual award, $1,200. Tenure, not limited. Further provisions as for the McMullen Regional Scholarships (see below), except that serious financial need is an essential criterion. (Not available in 1955.)

JESSEL STUART WHYTE SCHOLARSHIP . . . (Gift of Mrs. Anna Jessel Whyte in memory of her son.) Open to an entering student in the Sibley School of Mechanical Engineering. Annual award, $820. Tenure, not limited. Preference will be given to residents of Illinois, Iowa, Michigan, Minnesota, and Wisconsin. Further provisions as for McMullen Regional Scholarships (see below).

JOHN McMULLEN REGIONAL SCHOLARSHIPS . . . (Gift under the will of John McMullen.) Open to men, only, entering any division of the College of Engineering. Annual award, up to $900. Tenure, not limited. Forty or more scholarships awarded annually. Applicants will be selected on the basis of high scholastic achievement and other indications of qualities likely to produce leadership in engineering. Although financial need is not a factor in selecting the winners, full consideration will be given to need in fixing stipends.

JOHN McMULLEN INDUSTRIAL SCHOLARSHIPS . . . (Gift under the will of John McMullen.) Open to male secondary school graduates with at least one year's apprentice training in industry, who are sponsored by their employers. Terms otherwise as for John McMullen Regional Scholarships.

EDWARD P. BURRELL SCHOLARSHIPS . . . (Gift under the will of Katherine W. Burrell, in memory of her husband.) Open to men and women entering any division of the College of Engineering. Award, $400 for freshman year only. Need is an important factor in selecting the winners.

Scholarships and Grants-in-Aid for Upperclassmen

Students in their sophomore year and beyond may apply for scholarship aid through the Committee on Scholarships of the school in which they are enrolled (i.e., Civil Engineering, Mechanical Engineering, etc.). Applications are available in the office of the Director of each school.

Awards are of two general types: (1) those for which the principal qualification is financial need, and (2) those for which outstanding scholastic achievement is the chief criterion. In the first category are scholarships which are essentially grants-in-aid and which have variable stipends up to as much as full tuition in any year. Eligibility extends to any student not on scholastic probation.

The second category of awards, based on high scholastic and other attainments, consists of (1) a limited number of scholarships sponsored by industrial companies, mostly for students in their last two years of study, and (2) such vacancies as may occur in scholarships of this type usually awarded to entering students and subject to renewal. For some of these scholarships the stipends are as high as $1,000 a year; for others the amounts vary from token awards of $100 to $1,500 or more annually.

Loans

The University maintains substantial loan funds from which students may borrow after they have been in residence for two terms and provided they are in good standing. Loans bear no interest while the student is in the University, and usually not more than 4 percent annually after he leaves until repayment is made. Applications for loans should be made through the Office of the Dean of Men and Dean of Women.

Graduate Scholarships and Fellowships

Graduate students whose major subjects are in the various branches of engineering and who wish to be candidates for scholarship or fellowship aid should consult the *Announcement of the Graduate School* and make application to the Dean of the Graduate School or, for those who are candidates for the degree M.Aero.E., to the Director of the Graduate School of Aeronautical Engineering.

Prizes

Cornell University has a considerable number of funds given for the endowment of prizes to be awarded annually. Some of these prizes are open to competition by students of the University generally. A list of them, under the title *Prize Competitions,* will be mailed on request addressed to Cornell University Official Publication, Edmund Ezra Day Hall. Other prizes are open to competition particularly by students of the College of Engineering, as follows:

THE FUERTES MEDALS, established by the late Professor E. A. Fuertes. The endowment provides for two gold medals. One is awarded annually by the Faculty to that student of the School of Civil Engi-

neering who is found at the end of the first term of his senior year to have maintained the highest degree of scholarship in the subjects of this course, provided he has been in attendance at the University for at least two years. The other is awarded annually by the Faculty to a graduate of the School of Civil Engineering or the recipient of a graduate degree with major in civil engineering who has written a meritorious paper upon some engineering subject tending to advance the scientific or practical interests of the profession of the civil engineer. It is desired that papers be presented on or before April 15. If a paper is presented in printed form, it will not be received if it has been printed earlier than the next preceding April 15. Neither medal is awarded unless it appears to the Faculty of the School of Civil Engineering that there is a candidate of sufficient merit to entitle him to such distinction.

THE FUERTES MEMORIAL PRIZE IN PUBLIC SPEAKING, founded by the late Charles H. Baker, a graduate of the School of Civil Engineering of the class of 1886. Three prizes, one of $100, one of $40, and one of $20, are offered annually to all students of the Colleges of Engineering and Architecture who are in the fifth term or beyond, for proficiency in public speaking.

THE CHARLES LEE CRANDALL PRIZES, founded in 1916 by alumni of the School of Civil Engineering; prizes of $75, $50, $35, and $20. They are awarded each year by a committee appointed by the Director of the School of Civil Engineering for the best papers written by seniors or juniors in that School on suitable subjects, provided that both the substance and the written form of the papers submitted show real merit. The prizes were established to encourage original research, to stimulate interest in matters of public concern, and to inspire in the students an appreciation of the opportunities which the profession of civil engineering offers them to serve their fellow men as intelligent and public-spirited citizens. Papers must be submitted to the Director of the School of Civil Engineering on or before May 1 of each year.

SIBLEY PRIZES. Under a gift of Hiram Sibley, made in 1884, the sum of $100 is awarded annually in several prizes to fifth year students in mechanical engineering and electrical engineering, equally distributed, who have received the highest average in the preceding four years.

THE SILENT HOIST AND CRANE COMPANY MATERIALS HANDLING PRIZES of $125 and $75, established in 1940 by the Wunsch Foundation, are awarded each year for the best original papers on the subject of materials handling. This contest is open to undergraduate and graduate students of the College of Engineering.

THE J. G. WHITE PRIZE IN SPANISH. Through the generosity of James Gilbert White (Ph.D., Cornell, '85) three prizes, established in

1914, each of the value of $100, are offered annually. One of the three, which is awarded to an English-speaking student for proficiency in Spanish, is open to members of the junior and senior classes in the College of Engineering who are candidates for their first degree. No candidate is eligible unless he has completed successfully two terms of work in Spanish at Cornell University.

THE INSTITUTE OF AERONAUTICAL SCIENCES PRIZE. The "Student Branch Scholastic Award" of the Institute of Aeronautical Sciences is presented annually to the M.Aero.E. candidate who attains the best scholastic record for that academic year. The award consists of a certificate and a two-year free technical membership in the Institute.

Faculty and Staff

DEANE W. MALOTT, A.B., M.B.A., LL.D., President of the University.
SOLOMON CADY HOLLISTER, B.S., C.E., D.Eng., Sc.D., Dean of the College and Professor of Civil Engineering.
J. ELDRED HEDRICK, Ph.D., Assistant Dean of the College and Professor of Chemical Engineering.
JOHN F. McMANUS, C.E., Executive Assistant.
DONALD H. MOYER, B.S., M.A., Director of the Office of Student Personnel.
JEANETTE POOR, B.S., Librarian.

SCHOOL OF CIVIL ENGINEERING

NEPHI ALBERT CHRISTENSEN, B.S.C.E., M.S.C.E., Ph.D., Director of the School and Professor of Civil Engineering.
ANNETTE M. DIMOCK, Administrative Assistant, School of Civil Engineering.

EMERITUS PROFESSORS

SAMUEL LATIMER BOOTHROYD, M.S., Professor of Astronomy, Emeritus.
WALTER L. CONWELL, C.E., Professor of Highway Engineering, Emeritus.
HENRY SYLVESTER JACOBY, C.E., Professor of Bridge Engineering, Emeritus.
JOHN EDWIN PERRY, B.S. in C.E., Professor of Railroad Engineering, Emeritus.
ERNEST WILLIAM SCHODER, B.S., B.S. in Min., Ph.D., World War Memorial Professor of Experimental Hydraulics, Emeritus.
HERBERT HENRY SCOFIELD, M.E., Professor of Testing Materials, Emeritus.
ROMEYN Y. THATCHER, C.E., Professor of Civil Engineering, Emeritus.
PAUL HALLADAY UNDERWOOD, C.E., Professor in Civil Engineering, Emeritus.
CHARLES LEOPOLD WALKER, C.E., Professor of Sanitary Engineering, Emeritus.

PROFESSORS

DONALD J. BELCHER, B.S.C.E., M.S.E., Professor of Civil Engineering.
PAUL J. BIJLAARD, C.E., Professor of Structural Engineering.
MARVIN BOGEMA, B.S., M.C.E., Professor of Civil Engineering.
HARRY D. CONWAY, B.Sc. (Eng.), M.A., Ph.D., Professor of Mechanics.
JOHN C. GEBHARD, C.E., Professor of Civil Engineering.
HOWARD MERRILL GIFFT, B.S., M.S., C.E., Professor of Sanitary Engineering.
DWIGHT FRANCIS GUNDER, B.S., M.S., Ph.D., Professor of Mechanics and Head of the Department of Engineering Mechanics and Materials.
BENJAMIN K. HOUGH, S.B., S.M., Professor of Soil Mechanics.
HERBERT T. JENKINS, B.S. in C.E., M.S.E., Professor of Civil Engineering.
ANDRE L. JORISSEN, C.E., M.S., Sc.D., Professor of Civil Engineering.
ARTHUR J. McNAIR, B.S., M.S., C.E., Professor of Civil Engineering.
GEORGE WINTER, C.E., Ph.D., Professor of Structural Engineering.

ASSOCIATE PROFESSORS

CARL CRANDALL, C.E., Associate Professor of Civil Engineering and Secretary of the Engineering Faculty.

GORDON PAGE FISHER, B.E., D.Eng., Associate Professor of Civil Engineering.
CHARLES DONALD GATES, B.A., M.S., Associate Professor of Civil Engineering.
TAYLOR D. LEWIS, B.S.E., C.E., Associate Professor of Civil Engineering.
WILLIAM O. LYNCH, B.S.C.E., M.S., Associate Professor of Civil Engineering.
GEORGE B. LYON, B.S. in C.E., M.S., Associate Professor of Civil Engineering.
WILLIAM McGUIRE, B.S. in C.E., M.C.E., Associate Professor of Civil Engineering and Personnel Officer of the School of Civil Engineering.
MELVILLE STANTON PRIEST, B.S., M.S., Associate Professor of Civil Engineering.
LINCOLN REID, B.S., M.S., Associate Professor of Hydraulics.
FRED J. SPRY, C.E., M.C.E., Associate Professor of Surveying.

ASSISTANT PROFESSORS

WILLIAM L. HEWITT, A.B., B.C.E., M.C.E., Assistant Professor of Civil Engineering.
LEV ZETLIN, M.C.E., Ph.D., Assistant Professor of Civil Engineering.

INSTRUCTORS

ROBERT J. BRUNGRABER, B.S., Instructor in Civil Engineering.
SIDNEY AARON GURALNICK, B.S.C.E., Instructor in Civil Engineering.
RICHARD E. MASON, B.S.C.E., M.S.C.E., Instructor in Civil Engineering.
WILLIAM ZUK, B.S.C.E., M.S.E., Instructor in Civil Engineering.

RESEARCH ASSOCIATES

TA LIANG, B.E., M.C.E., Ph.D., Research Associate in Transportation.
DONALD R. LUEDER, B.S., M.C.E., Research Associate in Transportation.

SIBLEY SCHOOL OF MECHANICAL ENGINEERING

HARRY JOHN LOBERG, M.E., M.S. in Eng., Director of the School and Professor of Mechanical Engineering.
GEORGE RAYMOND HANSELMAN, M.E., M.S., Assistant Director of the School, Professor of Administrative Engineering, and Secretary of the Faculty of Mechanical Engineering.

EMERITUS PROFESSORS

CALVIN DODGE ALBERT, M.E., Professor of Machine Design, Emeritus.
VICTOR RAYMOND GAGE, M.E., M.M.E., Professor of Mechanical Engineering, Emeritus.
CLARENCE ELLSWORTH TOWNSEND, M.E., Professor of Engineering Drawing, Emeritus.
EDGAR HARPER WOOD, M.M.E., Professor of Mechanics of Engineering, Emeritus.

PROFESSORS

ARTHUR HOUGHTON BURR, B.S. in M.E., M.S. in M.E., Ph.D., Professor and Head of the Department of Machine Design.
STEPHEN FARRELL CLEARY, M.E., M.M.E., Professor and Head of the Department of Engineering Drawing.
BARTHOLOMEW JOSEPH CONTA, B.S., M.S. in Eng., Professor of Mechanical Engineering.
GEORGE BURTON DuBOIS, A.B., M.E., Professor of Mechanical Engineering.
FREDERICK SEWARD ERDMAN, B.S., B.S. in M.E., M.M.E., Ph.D., Professor of Mechanical Engineering.

DWIGHT FRANCIS GUNDER, B.S., M.S., Ph.D., Professor of Mechanics and Head of the Department of Engineering Mechanics and Materials.
JOSEPH OLMSTEAD JEFFREY, M.E., M.M.E., Professor of Engineering Materials.
CHARLES OSBORN MACKEY, M.E., Professor and Head of the Department of Heat-Power Engineering.
JOHN ROBERT MOYNIHAN, M.E., M.M.E., Professor of Engineering Materials.
HAROLD CHARLES PERKINS, M.E., Professor of Mechanics.
ANDREW S. SCHULTZ, JR., B.S. in A.E., Ph.D., Professor and Head of the Department of Industrial and Engineering Administration.
DENNIS GRANVILLE SHEPHERD, B.S. in Eng., Professor of Mechanical Engineering.

ASSOCIATE PROFESSORS

WILLIAM COOK ANDRAE, M.E., M.M.E., Associate Professor of Mechanical Engineering.
THOMAS J. BAIRD, B.Arch., M.R.P., Associate Professor of Mechanical Engineering.
ROBERT ERIC BECHHOFER, A.B., Ph.D., Associate Professor of Mechanical Engineering.
ROY EDWARDS CLARK, M.E., Associate Professor of Heat-Power Engineering.
DAVID DROPKIN, M.E., M.M.E., Ph.D., Associate Professor of Mechanical Engineering.
HOWARD NEWTON FAIRCHILD, M.E., E.E., Associate Professor of Mechanical Engineering.
NORMAN RUSSELL GAY, B.S. in M.E., M.S. in Eng., Associate Professor of Mechanical Engineering.
ROGER LOREN GEER, M.E., Associate Professor of Materials Processing.
ISRAEL KATZ, B.S. in M.E., M.M.E., Associate Professor of Mechanical Engineering.
HAMILTON HORTH MABIE, B.S. in M.E., M.S. in Eng., Ph.D., Associate Professor of Mechanical Engineering.
WILLIAM EMERSON MORDOFF, M.E., Associate Professor of Engineering Drawing.
FRED WILLIAM OCVIRK, B.S.C.E., M.S. in C.E., Associate Professor of Mechanical Engineering.
MARTIN WRIGHT SAMPSON, JR., B.S. in A.E., M.S. in Eng., Associate Professor of Mechanical Engineering.
BYRON WINTHROP SAUNDERS, B.S.E.E., M.S. in Eng., Associate Professor of Mechanical Engineering.
ROBERT HERMANN SIEGFRIED, M.E., Associate Professor of Mechanical Engineering.
EDWIN BEN WATSON, B.S. in M.E., M.S. in Eng., Associate Professor of Mechanical Engineering.

ASSISTANT PROFESSORS

ROBERT NELSON ALLEN, B.S. in A.E., Assistant Professor of Mechanical Engineering.
ANTOINE FRANCIS GAGNE, JR., B.S.M.E., M.S.M.E., Assistant Professor of Mechanical Engineering.
BENJAMIN GEBHART, B.S.E., M.S. in Eng., Ph.D., Assistant Professor of Mechanical Engineering.
ROBERT EYNON McGARRAH, B.S. in A.E., M.S. in M.E., Ph.D., Assistant Professor of Mechanical Engineering.

ELMER SYLVESTER MONROE, JR., B.S. in M.E., M.M.E., Assistant Professor of Mechanical Engineering.
RICHARD MAGRUDER PHELAN, B.S. in M.E., M.M.E., Assistant Professor of Mechanical Engineering.
ROBERT LOUIS WEHE, B.S. in M.E., M.S. in M.E., Assistant Professor of Mechanical Engineering.

INSTRUCTORS

ROGER WEST BROWNLOW, B.S.M.E., Instructor in Mechanical Engineering.
H. RUPPERT CARPENTER, Instructor-Technician in Mechanical Engineering.
JOHN CRONK CRISSEY, Instructor-Technician in Mechanical Engineering.
ANTHONY S. DISPENZA, Instructor-Technician in Mechanical Engineering.
RICHARD MEYER FAND, B.S.M.E., M.S.M.E., Instructor in Mechanical Engineering.
JOSEPH WILLIAM GAVETT, B.S., M.M.E., Instructor in Mechanical Engineering.
ROBERT JUDKINS HALL, B.S.M.E., Instructor in Mechanical Engineering.
ROBERT JOSEPH HEINZMAN, B.M.E., Instructor in Mechanical Engineering.
JOHN C. HUSON, Instructor-Technician in Mechanical Engineering.
JEREMY EDMONDS JOHNSON, B.M.E., Instructor in Mechanical Engineering.
HSU-KAN KAO, B.S.M.E., M.S. in I.E., Instructor in Mechanical Engineering.
RICHARD ALBERT KENYON, B.M.E., Instructor in Mechanical Engineering.
EDWARD VAN ORDER KRICK, B.S. in I.E., M.M.E., Instructor in Mechanical Engineering.
ANTHONY MALGIERI, JR., B.S.M.E., Instructor in Mechanical Engineering.
JAMES MENDON MOORE, B.M.E., Instructor in Mechanical Engineering.
W. EVERETT MORGAN, Instructor-Technician in Mechanical Engineering.
RAYMOND JOSEPH PAJKOWSKI, B.S.M.E., M.S. I.E., Instructor in Mechanical Engineering.
THOMAS MOORE SEDGWICK, B.M.E., Instructor in Mechanical Engineering.
STANISLAUS STEPHEN THOMAS, B.M.E., Instructor in Mechanical Engineering.
ERNEST S. YAWGER, Instructor-Technician in Mechanical Engineering.

SCHOOL OF ELECTRICAL ENGINEERING

CHARLES RUSSELL BURROWS, B.S.E. (in E.E.), A.M., E.E., Ph.D., Director of the School and Professor of Electrical Engineering.
ALEXANDER BERRY CREDLE, E.E., M.E.E., Ph.D., Assistant Director of the School and Professor of Electrical Engineering.

EMERITUS PROFESSOR

ROBERT FRANKLIN CHAMBERLAIN, M.E. (in E.E.), Professor of Electrical Engineering, Emeritus.

PROFESSORS

HENRY GEORGE BOOKER, B.A., M.A., Ph.D., Professor of Electrical Engineering.
LAWRENCE ADAMS BURCKMYER, JR., B.S. (in E.E), E.E., Professor of Electrical Engineering.
PAUL WILLIAM CHARTAN, B.S., M.A. (Physics), Visiting Professor of Electrical Engineering.
CASPER LEHMAN COTTRELL, A.B., Ph.D., Professor of Electrical Engineering, and Secretary of the Faculty of the School.

WILLIAM HARRY ERICKSON, B.S. in E.E., M.S. in E.E., Professor of Electrical Engineering.
MALCOLM STRONG McILROY, E.E., Sc.D. in E.E., Professor of Electrical Engineering.
TRUE McLEAN, E.E., Professor of Electrical Engineering.
MICHEL GEORGE MALTI, A.B., B.S. in E.E., M.E.E., Ph.D., Professor of Electrical Engineering.
WILBUR ERNEST MESERVE, B.S. (in E.E.), M.S., M.E.E. Ph.D., Professor of Electrical Engineering.
BURDETTE KIBBE NORTHRUP, M.E. (in E.E.), Professor of Electrical Engineering.
HOWARD GODWIN SMITH, E.E., M.E.E., Ph.D., Professor of Electrical Engineering.
EVERETT MILTON STRONG, B.S. in E.E., Professor of Electrical Engineering.
STANLEY WILLIAM ZIMMERMAN, B.S. in E.E., M.S. in E.E., Professor of Electrical Engineering.

ASSOCIATE PROFESSORS

PAUL DENZIL ANKRUM, B.S.E.E., A.B., M.S.E., Associate Professor of Electrical Engineering.
NELSON HOWARD BRYANT, E.E., M.E.E., Associate Professor of Electrical Engineering.
WALTER WENDELL COTNER, B.S. (in E.E.), E.E., M.E.E., Associate Professor of Electrical Engineering.
JAMES WATSON COX, B.A., M.A., Visiting Associate Professor of Electrical Engineering.
WILLIAM EDWIN GORDON, B.A., M.A., M.S., Ph.D., Associate Professor of Electrical Engineering.
CLYDE EDWIN INGALLS. E.E., Associate Professor of Electrical Engineering.
SIMPSON LINKE, B.S. in E.E., M.E.E., Associate Professor of Electrical Engineering.
HENRY STOCKWELL McGAUGHAN, B.S.E. (in Phys.), M.E.E., Associate Professor of Electrical Engineering.
BENJAMIN NICHOLS, B.E.E., M.E.E., Associate Professor of Electrical Engineering.
ROBERT E. OSBORN, B.S.E.E., Associate Professor of Electrical Engineering.
BEN WARRINER, III, B.S., M.S., Visiting Associate Professor of Electrical Engineering.

ASSISTANT PROFESSORS

MARSHALL H. COHEN, B.E.E., M.Sc., Ph.D., Assistant Professor in Electrical Engineering.
SANG C. DWU, B.S. in E.E., M.E.E., Ph.D., Assistant Professor of Electrical Engineering.
HOWARD LEAVENWORTH HEYDT, B.S., M.S., Visiting Assistant Professor in Electrical Engineering.
JOSEPH L. ROSSON, B.S. in E.E., M.S. in Engineering, Assistant Professor of Electrical Engineering.
NORMAN M. VRANA, B.E.E., M.E.E., Assistant Professor of Electrical Engineering.
ROBERT DOWNING WILSON, B.E.E., M.E.E., Assistant Professor of Electrical Engineering.

INSTRUCTORS

WILLIAM HENRY WARREN BALL, B.E., M.APP.SC., Instructor in Electrical Engineering.

LESTER FUESS EASTMAN, B.E.E., M.S., Instructor in Electrical Engineering.
RAYMOND A. ELLIOTT, B.S.E.E., M.S.E.E., Instructor in Electrical Engineering.
ALBERT SMITH JACKSON, B.S.E.E., M.S.E.E., Instructor in Electrical Engineering.
JAMES BARTLEY MATTHEWS, B.E.E., Instructor in Electrical Engineering.
LAWRENCE BYRON SPENCER, E.E., Instructor-Technician in Electrical Engineering.

RESEARCH ASSOCIATES

S. MICHAEL COLBERT, B.S.
EDWARD R. SCHIFFMACHER, E.E., M.E.E.

SCHOOL OF CHEMICAL AND METALLURGICAL ENGINEERING

FRED HOFFMAN RHODES, A.B., Ph.D., Director of the School, Herbert Fisk Johnson Professor of Industrial Chemistry, Professor of Chemical Engineering, and Personnel Officer of the School.

PROFESSORS

JAMES LAWRENCE GREGG, B.E., Professor of Metallurgical Engineering.
J. ELDRED HEDRICK, Ph.D., Professor of Chemical Engineering.
JOHN RAVEN JOHNSON, A.B., Ph.D., Professor of Organic Chemistry.
CLYDE WALTER MASON, A.B., Ph.D., Professor of Chemical Microscopy and Metallography.
JULIAN C. SMITH, B.Chem., Chem.E., Professor of Chemical Engineering.
CHARLES CALVERT WINDING, B.Chem.E., Ph.D., Professor of Chemical Engineering and Assistant Director for Chemical Engineering.

ASSOCIATE PROFESSORS

MALCOLM S. BURTON, B.S. in M.E., S.M. in M.E., Associate Professor of Metallurgical Engineering.
ROBERT L. Von BERG, B.S. in Chem.E., M.S. in Chem.E., Sc.D., Associate Professor of Chemical Engineering.
HERBERT F. WIEGANDT, B.S. in Chem.E., M.S. in Eng., Ph.D., Associate Professor of Chemical Engineering.
PETER HARRIOTT, B.Chem.E., Ph.D., Associate Professor of Chemical Engineering.
RAYMOND G. THORPE, B.Chem.E., M.Chem.E., Associate Professor of Chemical Engineering.

INSTRUCTOR-TECHNICIANS IN METALLURGICAL ENGINEERING

MORRIS L. HARPER, Instructor-Technician in Metallurgy.
RALPH W. HODGES, Instructor-Technician in Metallurgy.
DENNIS J. JOYCE, Instructor-Technician in Metallurgy.

GRADUATE SCHOOL OF AERONAUTICAL ENGINEERING

WILLIAM R. SEARS, B.Aero.E., Ph.D., Director of the School and Professor of Aeronautical Engineering.

PROFESSOR

ARTHUR KANTROWITZ, B.S., M.A., Ph.D., Professor of Aeronautical Engineering.

ASSOCIATE PROFESSORS

YUNG-HUAI KUO, B.S., M.A., Ph.D., Assoicate Professor of Aeronautical Engineering.
CARLO RIPARBELLI, Dr. C.E., Dr. A.E., L.D., Associate Professor of Aeronautical Engineering.
NICHOLAS ROTT, Dipl.-Ing., Ph.D., Associate Professor of Aeronautical Engineering.

DEPARTMENT OF ENGINEERING PHYSICS

LLOYD PRESTON SMITH, Ph.D., Director of the Department, Chairman of the Department of Physics, and Professor of Physics.

PROFESSORS

HENRY GEORGE BOOKER, Ph.D., Professor of Electrical Engineering.
CHARLES RUSSELL BURROWS, Ph.D., Director of the School of Electrical Engineering and Professor of Electrical Engineering.
DALE RAYMOND CORSON, Ph.D., Professor of Physics.
ALEXANDER BERRY CREDLE, Ph.D., Assistant Director of the School of Electrical Engineering and Professor of Electrical Engineering.
TREVOR RHYS CUYKENDALL, Ph.D., Assistant Director of the Department and Professor of Engineering Physics.
GUY EVERETT GRANTHAM, Ph.D., Professor of Physics.
DWIGHT F. GUNDER, Ph.D., Head of the Department of Engineering Mechanics and Materials, and Professor of Mechanics.
PAUL LEON HARTMAN, Ph.D., Professor of Physics.
MARK KAC, Ph.D., Professor of Mathematics.
ARTHUR KANTROWITZ, Ph.D., Professor of Aeronautical Engineering.
HENRI SAMUEL SACK, Ph.D., Professor of Engineering Physics.
WILLIAM REES SEARS, Ph.D., Director of the Graduate School of Aeronautical Engineering and Professor of Aeronautical Engineering.

ASSOCIATE PROFESSOR

BENJAMIN M. SIEGEL, Ph.D., Associate Professor of Engineering.

DEPARTMENT OF ENGINEERING MECHANICS AND MATERIALS

DWIGHT F. GUNDER, B.S., M.S., Ph.D., Head of the Department and Professor of Mechanics.

PROFESSORS

HARRY D. CONWAY, B.Sc. (Eng.), M.A., Ph.D., Professor of Mechanics.
TREVOR RHYS CUYKENDALL, Ph.D., Professor of Engineering Physics.
JOSEPH O. JEFFREY, M.E., M.M.E., Professor of Engineering Materials.
CLYDE W. MASON, A.B., Ph.D., Professor of Chemical Microscopy and Metallography.

JOHN R. MOYNIHAN, M.E., M.M.E., Professor of Engineering Materials.
HAROLD C. PERKINS, M.E., Professor of Mechanics.
HENRI SAMUEL SACK, Sc.D., Professor of Engineering Physics.

ASSOCIATE PROFESSORS

EDMUND TITUS CRANCH, B.M.E., M.M.E., Ph.D., Associate Professor of Mechanics.
ERIC V. HOWELL, C.E., M.C.E., Associate Professor of Mechanics.
FLOYD OWEN SLATE, B.S., M.S., Ph.D., Associate Professor of Engineering Materials.
DERALD A. STUART, B.S., M.S., Ph.D., Associate Professor of Engineering Materials.
HERBERT F. WIEGANDT, B.S. in Chem.E., M.S. in Eng., Ph.D., Associate Professor of Chemical Engineering.

ASSISTANT PROFESSORS

JAMES ALAN FAY, B.S., M.S., Ph.D., Assistant Professor of Mechanics.
LEO STEG, B.S., M.S., Ph.D., Assistant Professor of Mechanics.

INSTRUCTORS

HAROLD L. DIBBLE, Instructor.
CHARLES A. FARGO, Instructor.
ROBERT H. GOFF, Instructor.
ROBERT J. KELL, Instructor.
STANLEY OLSEFSKI, Instructor-Technician.
HARRY C. PETERSON, Instructor.
ALBERT E. SEAMES, Instructor.
GAYLEN A. THURSTON, Instructor.
NORMAN F. TODA, Instructor.

ENGINEERING COLLEGE COUNCIL

DEANE W. MALOTT, A.B., M.B.A., LL.D., ex officio, President of the University.
FORREST F. HILL, Ph.D., ex officio, Provost of the University.
SOLOMON CADY HOLLISTER, B.S., C.E., D.Eng., Sc.D., ex officio, Dean of the College.
ALEXANDER M. BEEBEE, M.E., President, Rochester Gas & Electric Company.
TELL BERNA, M.E., General Manager, National Machine Tool Builders' Association.
OLIVER E. BUCKLEY, Ph.D., former Chairman, Bell Telephone Laboratories.
JAMES R. DONNALLEY, Jr., Ph.D., Manager, Silicone Products Department, General Electric Company.
LEWIS R. GATY, M.E.E., Manager, Engineering Department, Philadelphia Electric Company.
ISAAC HARTER, B.S., Chairman, Babcock & Wilcox Company.
KARL J. NELSON, B.Ch.E., Assistant Director, Planning, Chemical Products Department, Esso Standard Oil Company.
F. W. SCHEIDENHELM, C.E., Consulting Engineer.
V. M. SCHNEE, B.Chem., Executive Director, Materials Advisory Board, National Research Council.
J. CARLTON WARD, Jr., M.E., President, Vitro Corporation of America.
CHARLES S. WHITNEY, M.C.E., Amman & Whitney, Consulting Engineers.

COUNCIL OF THE ENGINEERING EXPERIMENT STATION

SOLOMON CADY HOLLISTER, B.S., C.E., D.Eng., Sc.D., Director of the Station and Chairman of the Council.

NEPHI ALBERT CHRISTENSEN, B.S.C.E., M.S.C.E., Ph.D., in Charge of Research in Civil Engineering.

HARRY J. LOBERG, M.E., M.S. in Eng., in Charge of Research in Mechanical Engineering.

CHARLES RUSSELL BURROWS, B.S.E. (in E.E.), A.M., E.E., Ph.D., in Charge of Research in Electrical Engineering.

FRED HOFFMAN RHODES, A.B., Ph.D., in Charge of Research in Chemical Engineering and Metallurgical Engineering.

WILLIAM R. SEARS, B.Aero.E., Ph.D., in Charge of Research in Aeronautical Engineering.

LLOYD P. SMITH, B.S. in E.E., Ph.D., in Charge of Research in Engineering Physics.

DWIGHT F. GUNDER, B.S., M.S., Ph.D., in Charge of Research in the Department of Engineering Mechanics and Materials.

School of Civil Engineering

EQUIPMENT

THE PRINCIPAL building occupied by the School of Civil Engineering is Lincoln Hall, containing classrooms, drafting rooms, and laboratories.

The laboratories for sanitary engineering and airphoto analysis and photogrammetric work are located in Lincoln Hall. The sanitary laboratory provides for physical, chemical, and bacteriological analyses of water and sewage and for research in general. The airphoto analysis and photogrammetric laboratories provide for interpretation and use of airphotos in all types of surveying and regional planning activities.

A fully equipped and manned machine shop is also provided in Lincoln Hall, which gives support to laboratory instruction and research.

Facilities in Thurston Hall include the testing laboratory, equipped for a wide variety of tests of cement, concrete, timber, structural steel, and other construction materials used by civil engineers.

The soil mechanics laboratory is located in a separate building and has facilities for instruction, standard laboratory work, and specialized research in soil mechanics.

The highway laboratories are housed in separate buildings and are equipped for making standard tests and for research in highway engineering. Astronomical equipment in the Fuertes Observatory includes the instruments required for determining time, latitude, longitude, and azimuth.

Hydraulic laboratories, situated at the outlet of Beebe Lake, are under the jurisdiction of this School. In addition to student instruction and research, these laboratories provide facilities for hydraulic investigations carried on in cooperation with government agencies and private companies.

COURSES OF STUDY

The courses of study offered by the School of Civil Engineering lead to the degree of Bachelor of Civil Engineering. The courses are all planned to provide fundamental instruction for the practice of the profession. To meet this objective, the major portion of the curriculum is definitely prescribed, both as to technical content and humanistic studies. Each student, however, is permitted to choose elective courses in various

fields which can be planned to intensify his training in a specific area or to increase his general background.

Combined Programs in Law, Business and Public Administration, and City and Regional Planning

The School participates with the Law School, the School of Business and Public Administration, and the College of Architecture in combined programs during the fifth year; in this way the student in civil engineering may complete the requirements for the appropriate advanced or graduate degree in a period one year less than that normally required. The programs are described on pages 37 and 38.

CURRICULUM (B.C.E.)

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	2	3
	English 111, Introductory Course	3	3	0
	Engineering 2001, Drawing	3	0	7½
	Total	15		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 2002, Drawing	3	0	7½
	Engineering 2111, Elementary Surveying	2	0	5
	Total	17		

In addition to these courses, all freshmen must satisfy the University's requirements in military training and physical education.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 113, Electricity and Magnetism	2	3	2½
	Chemistry 301, Organic Chemistry or Chemistry 402, Physical Chemistry	2	2	0
	Geology 113, Engineering Geology (or Economics 107)	3	2	5
	Engineering 2112, Advanced Surveying	3	2	2½
	Engineering 1151, Mechanics-Statics	3	3	0
	Total	16		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 4	Physics 114, Physical Electronics and Optics	2	3	2½
	Chemistry 402, Physical Chemistry or Chemistry 301, Organic Chemistry	2	2	0
	Economics 107, Introduction to Economics or Geology 113	3	3	0
	Engineering 2113, Route and Aerial Surveying	3	1	5
	Engineering 1152, Mechanics-Dynamics	3	3	0
	Engineering 1153, Strength of Materials	3	3	0
	Total	16		

In addition to these courses, all sophomores must satisfy the University's requirements in military training and physical education.

TERM 5	Engineering 2103, Summer Survey Camp	5	0	0
	Engineering 1134, Strength of Materials	3	3	0
	Engineering 1211, Materials (or 2901)	3	2	2½
	Engineering 2301, Fluid Mechanics	3	3	0
	Engineering 2501, Microbiology in Engineering (or 2725)	3	2	2½
	Engineering 2701, Elementary Structural Analysis	3	2	2½
	Engineering 2602, Transportation (or Accounting 3231)	3	3	0
	Total	23		
TERM 6	Engineering 2901, Construction Methods (or Materials 1211)	3	3	0
	Engineering 2302, Hydraulics	3	2	2½
	Engineering 3231, Accounting (or 2602)	3	2	2½
	Engineering 2702, Elements of Metals and Timber Structures	3	0	7½
	Engineering 1145, Applied Mathematics	3	3	0
	Engineering 2725, Soil Mechanics (or 2501)	3	2	2½
	Total	18		
TERM 7	Engineering 1212, Materials Laboratory (or 2412)	3	1	5
	Engineering 2704, Statically Indeterminate Structures (or Speech 101)	3	3	0
	Engineering 2502, Water Supply and Treatment (or 2503)	3	2	2½
	Engineering 2715, Reinforced Concrete Design (or 2610)	3	1	4
	Engineering 2902, Engineering Law (or 2903)	3	3	0
	Engineering Economics 203, Money, Currency, and Banking	3	3	0
	Total	18		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 8	Engineering 2412, Hydraulics (or Materials 1212)	3	3	0
	Engineering 2503, Sewerage and Sewage Treatment (or 2502)	3	2	2½
	Engineering 2720, Foundations (or 2904)	3	2	2½
	Engineering 2610, Highway Engineering (or 2715)	3	2	2½
	Engineering 2903, Economics of Engineering (or 2902)	3	3	0
	Public Speaking 101 (or 2704)	3	3	0
	Total	18		
TERM 9	History 165, Science in Western Civilization	3	3	0
	Engineering 2713, Structural Design (or 2720)	3	0	6
	Engineering 3541, Heat Power I	3	2	2
	Engineering 4931, Electrical Engineering	3	2	2½
	Electives (Free)	6		
	Total	18		
TERM 10	Engineering 3542, Heat Power II	2	2	0
	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 2904, Public Administration (or 2713)	3	3	0
	History 166, Science in Western Civilization	3	3	0
	Industrial and Labor Relations 293, Survey of Industrial and Labor Relations	3	3	0
	Electives (Free)	6		
	Total	20		

Grand total for ten terms: 181 credit hours including summer survey camp, but not including military training or physical education.

COMBINED PROGRAM IN CIVIL ENGINEERING AND BUSINESS AND PUBLIC ADMINISTRATION

(B.C.E. and M.B.A. or M.P.A.)

During the fifth year the student will be registered in both Schools. A specialized program will be worked out with the School of Business and Public Administration within the framework of the Civil Engineering curriculum as amended by the following approved substitutions:

BPA 110, Administrative Accounting, for Eng. 3231

BPA 140, Finance, for Economics 203.

BPA 120, 121, Economic and Business History, for History 165, 166

BPA 100, 101, Administration, for Eng. 2904 and ILR 293

Under special circumstances, and by petition to the Faculty, other substitutes may be approved.

During the sixth year, and after receiving the B.C.E. degree, the student will be registered only in the School of Business and Public Administration.

COMBINED PROGRAM IN CIVIL ENGINEERING AND CITY AND REGIONAL PLANNING
(B.C.E. and M.R.P.)

After approval by both the School of Civil Engineering and the College of Architecture, the fifth year student may follow a special program within the framework of the Civil Engineering curriculum as amended by the following approved substitutes:

BPA 218, Municipal Administration, for Eng. 2904
Arch. 700, 401, History of Architecture and City Planning, for History 165, 166
Arch. 710, 711, Principles and Practice of City Planning, for Econ. 203 and ILR 293
Arch. 718 or 720, Field Problems in Urban Planning, for three elective courses

Under special circumstances, and by petition to the Faculty, other substitutes may be approved.

During the sixth year, and after receiving the B.C.E. degree, the student will be registered in the College of Architecture as a candidate for the M.R.P. degree.

Sibley School of Mechanical Engineering

EQUIPMENT

THE SIBLEY SCHOOL of Mechanical Engineering, named in recognition of important gifts made by Hiram Sibley and his son, Hiram W. Sibley, occupies a group of buildings at the north end of the campus. In addition to the Sibley building, the new Kimball Hall, housing all equipment related to materials processing, is now available at the south end of the campus adjacent to the new Thurston Hall for engineering mechanics and materials testing. The school is provided with a central working library in Sibley Dome, and many of the departments also maintain special working and reference libraries.

Numerous laboratories and shops are available for carrying on the many activities of the School of Mechanical Engineering, as follows: the materials testing laboratory, heat treatment laboratory, and metallography laboratory, for determination of the physical properties of engineering materials under various conditions; the machine design laboratory, for instruction and research in photoelasticity, balancing, vibration, stress, lubrication, and wear of machines and machine members; the steam laboratory, for instruction and research involving steam power; the internal-combustion engine laboratory, for work with this type of power equipment; the M.E. hydraulics laboratory, a pump-operated laboratory for hydraulic problems; the lubrication laboratory, for determination of the physical properties of lubricants; the refrigeration laboratory, for the study of refrigeration; the fuel testing laboratory, for determination of the composition and calorific value of all types of fuel; the micromotion laboratory, for motion and time study; the constant-temperature room, and the heat transfer, heating, ventilating, air conditioning laboratories; a series of research laboratories; the materials processing laboratories—the woodworking and pattern shop, the machine shop and the gage laboratory; the laboratory boiler house; and the University heating plant and power house.

OUTLINE OF THE INSTRUCTION

The object of the instruction in this School is to lay as broad and substantial a foundation of general and technical knowledge and provide as much training in engineering practice in the fields of mechan-

ical engineering and engineering administration as can well be imparted in a school.

Students of mechanical engineering are instructed primarily in the utilization of nature's sources of energy and materials for the benefit of mankind, through the development and application of prime movers, machinery, and processes of manufacture; thus, they have to do mainly with things dynamic. The province of the mechanical engineer includes the design, construction, operation, and testing of steam engines, steam turbines, steam generating apparatus, and power plant auxiliaries, internal combustion engines, hydraulic machines, pumping engines, railway equipment, compressed-air machines, ice making and refrigerating machinery, equipment for heating and ventilating and air conditioning, machine tools, mill equipment, and transmission machinery. The work of the mechanical engineer further includes the planning of power plants and factories, the selection and installation of their equipment, the development of systems of operation and manufacturing processes, and the organization and administration of plants and industries. In addition, the mechanical engineer may engage in scientific research in the innumerable branches of this field.

The general plan of the curriculum is to give a thorough training in mathematics and the basic sciences of physics and chemistry leading to the fundamental engineering sciences and technological courses. Parallel with this training are a group of courses in the social sciences and liberal fields to develop a better understanding of the social, political, and economic world in which the engineer must assume responsibility for leadership. The outline of the course of study shows how the training is integrated as well as the depth and scope of the subject matter to give the young engineer a sound foundation for his future professional growth.

Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

Project and Electives

During the last three years, provision is made for the choice of elective courses and a senior project in the student's major field of study. His project may be an individual one or a group project in a technical, managerial, or related field for the purpose of applying to one or more basic problems the fundamental concepts he has been taught in the preceding years and for the purpose of developing the ability to do work of an original nature.

The project may be in any one of many branches, such as management, industrial engineering, heat-power engineering, internal combus-

tion engines, heat engineering, heating, ventilating and air conditioning, refrigeration engineering, automotive engineering, aeronautical engineering, mechanical design, experimental stress analysis, design development, advanced mechanics and strength of materials, engineering materials, experimental engineering, materials processing, tool engineering, welding design, structural engineering, physics, electrical engineering, and other fields related to mechanical engineering.

The 29 hours of electives in the curriculum provide an opportunity for the student to select a wide variety of courses offered in the University, depending upon his interests and objectives. To ensure a reasonable breadth of training in fields other than engineering, beyond those courses already specified, the student must elect nine credit hours of work from the fields of English, government, history, languages, philosophy, psychology, economics, sociology and anthropology, speech and drama, literature, music, fine arts, or the classics. To acquire some depth of training, it is strongly urged that a student take at least six credit hours of work in a given field.

A minimum of eight credit hours of electives must be approved courses in the College of Engineering. Usually these courses will be related to the student's project, but he does have the opportunity to pursue engineering specialties of great interest to him.

INDUSTRIAL AND ENGINEERING ADMINISTRATION

The training of engineers for the field of production engineering or industrial engineering has been an integral part of the Sibley School of Mechanical Engineering for the past fifty years. The increasing scientific developments underlying the operation of works and plants in many industries have put additional emphasis on the need for a sound background in such areas as materials, design, statistical procedures, materials processing, gaging and inspection, methods engineering, cost accounting and production engineering including product analysis, plant layout, engineering economy, and production control, all of which are required in the curriculum.

The emphasis is on the engineering aspects, with due regard for the importance of the human and personnel factors involved in successfully organizing and managing an industrial enterprise.

The student interested in this field can select suitable electives to further his training in such areas as psychology, industrial marketing and research, advanced statistics for quality control and analysis, personnel management, industrial organization, advanced methods engineering, and production control, or additional work in economics or in standard costs and control.

The existence of a School of Industrial and Labor Relations, a College of Arts and Sciences, and other divisions of the University on the

same campus as the College of Engineering makes possible combinations of elective courses that are available at few other technical schools in the country.

PREPARATION FOR AERONAUTICAL ENGINEERING

The program leading to the degree M.Aero.E., described on pages 62-65 of this Announcement, usually requires three or four terms of graduate study. Candidates for the B.M.E. degree may be able to complete the entire program in a total of six academic years by starting their aeronautical courses during their fourth and fifth years. This saves from one term to a year of residence. To accomplish this a candidate should select his elective courses from the M.Aero.E. program and should also, if possible, carry out a fifth year project in a related subject. This should be planned in consultation with the Class Adviser and a member of the Aeronautical Engineering Faculty. The privilege of taking graduate courses is restricted to undergraduates who fulfill the requirements stated on pages 64-65.

INDUSTRIAL COOPERATIVE PROGRAM

The School participates in the Engineering Industrial Cooperative Program providing periods of industrial experience interspersed among regular terms of study. The Program is described on pages 12-13.

EMPLOYMENT AFTER GRADUATION

Graduates in mechanical engineering find employment in the design, construction, testing, and operation of prime movers and other machinery, and of complete plants in their own related fields, and in sales engineering and industrial research and development. They serve also as planners of new projects and processes, and as aeronautical engineers, air-conditioning engineers, industrial engineers, power-plant engineers, refrigeration engineers, research engineers, and teachers of engineering —to mention only a few of the many special fields open to them. With the instruction in liberal subjects and those related to administration and management coupled with the technical training, they have special qualifications to develop into leaders in their chosen fields.

SCHOLASTIC REQUIREMENTS

A student in the School of Mechanical Engineering who fails in any term to earn a passing grade in 15 hours, with a grade of 70 or better in 11 hours, may be placed on probation. If he fails in any term to pass 12 hours he may be dropped from the University.

CURRICULUM (B.M.E.)

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	2	3
	English 111, Introductory Course	3	3	0
	Engineering 3111, Drawing and Descriptive Geometry	3	1	5
	Engineering 3001, Introductory Engineering	1	2	0
	Total	16		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 3112, Mechanical Drafting	3	1	5
	Engineering 3002, Introductory Engineering	2	2	0
	Total	17		

In addition to taking these courses, all freshmen must satisfy the University requirements in physical education and in military training.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301, Organic Chemistry	2	2	0
	Engineering 1151, Mechanics—Statics	3	3	0
	Engineering 3241, Statistics	3	2	2½
	Engineering 6110, Casting, Working, and Welding of Metals (or Engineering 3406)	2	1	2
	Total	16		
TERM 4	Physics 118, Electronics and Optics	3	3	2½
	Chemistry 402, Physical Chemistry	2	2	0
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 1155, Applied Mathematics	3	3	0
	Engineering 3262, Methods Engineering	3	1	5
	Engineering 3406, Materials Processing (or Engineering 6110)	2	1	2½
	Total	16		

In addition to taking these courses, all sophomores must satisfy the University requirements in physical education and in military training.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 5	Engineering 1221, Engineering Materials	3	3	0
	Engineering 3351, Mechanism	3	2	2½
	Engineering 3501, Thermodynamics	4	4	0
	Engineering 1152, Mechanics—Dynamics	3	3	0
	Engineering 3246, Industrial Accounting	2	2	0
	Engineering 3404, Production Machine Tools (or Engineering 3405)	2	1	2½
	Electives	3	Arr.	Arr.
	Total	20		
TERM 6	Engineering 1222, Engineering Materials	3	3	0
	Engineering 3352, Dynamics of Machinery	3	2	2½
	Engineering 3520, Fluid Dynamics	3	3	0
	Engineering 3247, Principles of Cost Control	3	2	2½
	Engineering 3504, Fuels	2	2	0
	Engineering 3405, Gage Laboratory (or Engineering 3404)	1	0	2½
	Electives	3	Arr.	Arr.
	Total	18		
TERM 7	Engineering 3503, Heat Transfer	3	2	2½
	Engineering 3353, Design of Machine Members	3	1	5
	Engineering 1231, Engineering Materials Lab.	3	1	2½
	Engineering 3521, Steam Power	2	2	0
	Engineering 3522, Combustion Engines	2	2	0
	Engineering 3263, Production Engineering	3	1	5
	Electives	3	Arr.	Arr.
	Total	19		
TERM 8	Engineering 3354, Machine Design	3	1	5
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 6112, Metallurgy of Casting, Working, and Welding	2	2	0
	Engineering 3523, Refrigeration and Air Conditioning	2	2	0
	Engineering 3524, Heat Power Laboratory	3	0	5
	Engineering 3264, Production Engineering	3	1	5
	Electives	3	Arr.	Arr.
	Total	19		
TERM 9	Project	3	Arr.	Arr.
	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 1154, Strength of Materials	3	3	0
	Economics 107, Introduction to Economics (or Public Speaking 101)	3	3	0
	Electives	8	Arr.	Arr.
	Total	20		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 10	Project	3	Arr.	Arr.
	Engineering 4933, Electrical Engineering	3	2	2½
	Public Speaking 101 (or Economics 107)	3	3	0
	Engineering 3041, Nonresident Lectures	1	1	0
	Electives	9	Arr.	Arr.
	Total	19		
	Total for ten terms	180		

School of Electrical Engineering

EQUIPMENT

THE LECTURE and recitation rooms of the School of Electrical Engineering occupy the greater part of Franklin Hall. Laboratories are in Franklin Hall, on the second floor of Rand Hall, and in two annexes. The new electrical engineering building, Phillips Hall, now under construction, will house the instructional, administrative, and research facilities of the School in the near future. The library, established through a generous gift from the McGraw-Hill Book Company in memory of the first director of the School, and known as the Alexander Gray Memorial Library, is housed in Sibley Dome as a part of the combined Mechanical, Electrical, and Civil Engineering Library.

Laboratory facilities include the electrical machinery laboratories, with a great variety of both direct- and alternating-current machinery; the electrical measurements and standardization laboratory, equipped for instruction in the checking of meters and secondary standards and in the precise measurements of electrical and magnetic quantities; the radio and communication laboratory, including microwave and ultra-high-frequency laboratories; the industrial electronics laboratory, for the study of electronic power and control devices; the electronics apparatus and project laboratory, for the construction of electronic apparatus by students according to their own designs; the vacuum tube laboratory, for the construction and testing of electron tubes; the servomechanism laboratory, for the study of closed loop control systems; the illumination laboratory; and the television and pulse technique laboratory.

In addition to these general laboratories, facilities available for instruction and research include the radio-astronomy laboratory, engaged primarily in basic research; the antenna laboratory, for the investigation of directional characteristics of antennas; the ionospheric laboratory; the high voltage research laboratory; the a-c network calculator, designed to study problems arising in complex electrical networks; and the fluid network analyzer, designed to solve problems of pressure and flow in fluid distribution systems by means of electrical analogies.

CURRICULUM

The curriculum leading to the degree of Bachelor of Electrical Engineering is intended to create in the student an understanding of the meaning and the application of those laws of nature which are basic in

the practice of electrical engineering and to develop a general knowledge of the origins and the trends of modern society. Through the first eight terms, all students follow the same program of technical studies; in the last two terms interest in one or more of the subdivisions of electrical engineering may be developed. Courses in administration and the humanities are distributed throughout the curriculum in accordance with the student's increasing comprehension. In all, there are thirty-three hours of courses in the administrative field and the humanities in the curriculum. Of these, twenty-seven hours are specified, and six are elective. The student may substitute other courses in this category for fifteen of the twenty-seven specified. In addition to these thirty-three hours, there are twelve free electives that the student may take in the humanities if he so desires.

Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature for the second term of the introductory course in English.

The curriculum reflects the convictions of the Faculty that the modern engineer is fully equipped only if his traditional ability to manage devices and processes is accompanied by a knowledge of men and an awareness of their needs.

INDUSTRIAL COOPERATIVE PROGRAM

The School participates in the Engineering Industrial Cooperative Program, providing periods of industrial experience interspersed among regular terms of study. The Program is described on pages 12-13.

THE FRESHMAN YEAR

Since the curriculum of the freshman year in electrical engineering is essentially the same as the curricula in mechanical engineering and engineering physics, transfer of a student between any two of these curricula may occur before the third term without loss of time. The freshman curricula in civil engineering and in chemical and metallurgical engineering differ to such an extent from the curriculum in electrical engineering that a transfer into one of these curricula is almost certain to require a lengthening of the student's program.

CLASS ADVISERS

An experienced member of the Faculty acts as Adviser to each new freshman class that enters the School of Electrical Engineering. With the sophomore year the class is assigned to another Adviser who generally continues to serve until the class graduates, counseling each student in regard to curriculum, registration, scholarship, and other matters of the

academic program. In addition, he tries to be helpful in the solution of personal problems that the student may bring to him.

Because responsibility for approval of the registration of each student is vested in the Class Adviser, no cancellation of courses or other changes in program may be initiated without his knowledge and approval. If the student desires a program of courses which the Class Adviser does not approve, the student may seek approval of the program by petition to the Faculty of the School of Electrical Engineering.

SCHOLASTIC REQUIREMENTS

A student in the School of Electrical Engineering who does not receive a passing grade in every course for which he is registered, and who fails in any term or summer session to maintain an average grade of at least 70 per cent, may be dropped or placed on probation.

ELECTIVE COURSES

The curriculum in electrical engineering allows each student to choose a considerable number of elective courses during the latter years of the curriculum. Some of the elective credit hours can be chosen without restriction, some must be nontechnical in the sense that they lie completely outside the field of engineering technology, and some must be either advanced courses in the sciences on which electrical engineering is based or in electrical engineering. The opportunity thus afforded for contact with the broader phases of education offered by the University as a whole tends to expand the student's mental horizon and to develop him as a well-rounded citizen.

The program of the fifth year includes two three-hour courses, designated as "Project." These are elective courses in the important respect that the student makes his own selection of the topic or problem which he will investigate under the general supervision of a Faculty member. It is expected that each student will choose a problem closely related to his major interest in electrical engineering.

Six elective credit hours must be selected from fields of study which develop an interest outside electrical engineering and its supporting sciences. The list of subjects that follows represents fields from which courses of the nontechnical category have been approved in the past. Other subjects may be approved upon petition.

Architecture	Economics	Geology
Astronomy	English	Government
Biology	Entomology	History
Botany	Fine Arts	Industrial and Labor Relations
Dramatics	Floriculture	Journalism

Limnology	Music	Psychology
Literature	Ornithology	Sociology
Meteorology	Paleontology	Speech
Modern Languages	Philosophy	Zoology

Nine elective credit hours must be selected from courses in electrical engineering, mathematics, or physics. At least one of the courses so selected must contain laboratory work. A course so selected must not contain a great amount of material that is essentially equivalent to that in required courses in the curriculum.

Acceptable courses are designated as follows:

1. Courses in electrical engineering numbered less than 4900.
2. Courses in mathematics numbered greater than 300.
3. Courses in physics numbered greater than 209, except 236.

The courses, elected in fulfillment of the nine-hour technical elective requirement, serve as a core for advanced studies in a particular phase of electrical engineering. Students may specialize in power systems and machinery, in industrial electronics and control, in radio and communications, in illumination, or in applied mathematics and physics. Alternatively, some students find it advisable to take advanced courses that lie in more than one of these specialties.

In addition to the fifteen elective hours enumerated above, there are twelve free electives. These may be chosen from among any courses in the University for which prerequisites are satisfied, including those in the foregoing list. By carefully planning the use of electives, students may carry out extensive programs of study in other divisions of the University during the fifth year of the curriculum.

Credit hours in advanced military or air or naval science and tactics may be counted, to the extent of nine, toward the requirements of the baccalaureate degree. Six hours so credited are considered to lie within the free-elective area of the curriculum and three in the "nontechnical" group.

Combined Programs in Law and Business and Public Administration. Students in the School of Electrical Engineering may apply for admission to special programs which will permit the completion of requirements for the B.E.E. degree in five years and the LL.B. in seven years or the M.B.A. or M.P.A. in six years. Such a program requires approval of the two schools involved and double registration in the fifth year. This results in reducing the time required for the second degree by a year.

War Service Experience and Courses. Provision is made for veterans to obtain some credit toward the baccalaureate degree for war service experience or courses. The student should consult his Class Adviser.

CURRICULUM (B.E.E.)

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Chemistry	3	2	3
	Engineering 3117, Descriptive Geometry	2	0	5
	Engineering 3402, Machine Tool Processes	2	1	2½
	(or Engineering 6110, Casting, Working, and Welding of Metals)	(2)	(1)	(2)
	English 111, Introductory Course	3	3	0
	Total	16		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Heat, Sound, and Geometrical Optics	3	3	2½
	Chemistry 106, General Chemistry	3	2	3
	Engineering 3118, Mechanical Drafting	2	0	5
	Engineering 6110, Casting, Working, and Welding of Metals	2	1	2
	(or Engineering 3402, Machine Tool Processes)	(2)	(1)	(2½)
	English 112, Introductory Course	3	3	0
	Total	16		

In addition to the above courses, freshmen are required to take military training and physical education.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Engineering 1151, Mechanics	3	3	0
	Engineering 2131, Surveying	1	0	2½
	Engineering 3231, Accounting	3	2	2½
	Engineering 4110, Basic Electrical Engineering	3	2	3
	Total	16		
TERM 4	Mathematics 607, Applied Mathematics for Electrical Engineers	3	3	0
	Physics 118, Physical Optics and Atomic Physics	3	3	2½
	Engineering 1152, Mechanics	3	3	0
	Engineering 3530, Engineering Thermodynamics	3	3	0
	Engineering 4111, Basic Electrical Engineering	3	2	3
	Total	15		

In addition to the above courses, sophomores are required to take military training and physical education.

Class Advisers may permit substitution of a course from the approved nontechnical fields (page 48) for Engineering 3231.

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 5	Chemistry 401, Physical Chemistry	3	3	0
	Economics 107, Introduction to Economics	3	3	0
	Engineering 1153, Mechanics of Materials	3	3	0
	Engineering 4112, Alternating-Current Circuits	3	2	3
	Engineering 4116, Electric Circuit Laboratory	3	1	3
	History 165, Science in Western Civilization	3	3	0
	Total	18		
TERM 6	Engineering 1223, Engineering Materials	3	3	0
	Engineering 4113, Transmission Lines and Filters	3	2	3
	Engineering 4121, Electron Tubes and Circuits	4	2	6
	Engineering 4216, Electrical Machinery Laboratory	4	2	3
	History 166, Science in Western Civilization	3	3	0
	Total	17		

Class Advisers may permit substitution of courses from the approved nontechnical fields (page 48) for History 165 and History 166 and substitution of another economics course for Economics 107.

TERM 7	Engineering 2331, Fluid Mechanics	3	3	0
	Engineering 4122, Electronic Circuit Elements	4	3	3
	Engineering 4221, Alternating Current Machinery	4	2	3
	Engineering 4114, Transients in Linear Systems	3	2	3
	Public Speaking 101	3	3	0
	Total	17		
TERM 8	Physics 214, Atomic, Nuclear, and Electron Physics	3	3	0
	Engineering 3341, Machine Design	4	3	2½
	Engineering 4123, Electronic Circuit Elements	4	3	3
	Engineering 4226, Electrical Machinery Laboratory	4	2	3
	Psychology 101, Introduction to Psychology	3	3	0
	Total	18		

Class Advisers may permit substitution of a course from the approved nontechnical fields (page 48) for Psychology 101.

TERM 9	Engineering Reports 4021	3	3	0
	Free Electives	6	—	—
	Nontechnical Electives (see page 48)	3	—	—
	Senior Project 4091	3	—	—
	Technical Electives (see page 49)	3	—	—
	Total	18		

		CREDIT HOURS	LEC. REC. HOURS	LAB. COMP. HOURS
TERM 10	Free Electives	6	—	—
	Nonresident Lectures	1	1	0
	Nontechnical Electives (see page 48)	3	—	—
	Senior Project 4092	3	—	—
	Technical Electives (see page 49)	6	—	—
	Total	19		
	Grand Total for 10 Terms	170 hours		

School of Chemical and Metallurgical Engineering

EQUIPMENT

THE SPECIALIZED training in chemical and metallurgical engineering is given in Olin Hall of Chemical Engineering and in the laboratories for foundry practice and metal working. The courses in chemistry are given in Baker Laboratory of Chemistry.

Olin Hall of Chemical Engineering was provided through the generosity of Franklin W. Olin as a memorial to his son Franklin W. Olin, Jr. This modern and well equipped building, with about 105,000 square feet of available floor space, provides lecture-room, recitation-room, and laboratory facilities for the instruction in chemical and metallurgical engineering. The unit operations laboratory, which is about one hundred feet long and fifty feet wide, extends through three floors and houses semi-plant-scale equipment for both instruction and research. It is served by a traveling crane and by its own shops and analytical laboratory. A considerable part of the building is subdivided into unit laboratories for advanced and graduate students.

OUTLINE OF THE INSTRUCTION

The purpose of the instruction in this School is to train qualified young men for effective professional and administrative work in the chemical or the metallurgical industries. In the required curriculum some work in cultural subjects is included. By providing elective work in the later years the curriculum makes it possible for the student to take courses either in subjects outside the field of his major interest or in special or advanced technical subjects within that field.

The first four terms provide thorough training in chemistry, mathematics, and physics and the other basic subjects on which the specific professional training is based. The later terms include more strictly technical and more advanced courses in engineering and in chemistry and the fundamental courses in the specific fields of chemical and metallurgical engineering. The last two terms include the more advanced work in engineering and in the specialized fields. (For an outline of the course of study, see below.)

Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department

of English, to substitute other courses in English or English literature in the second term.

SCHOLASTIC REQUIREMENTS

A student in the School of Chemical and Metallurgical Engineering who does not receive a passing grade in every course for which he is registered, or who fails in any term or summer session to maintain an average grade of 75 per cent, may be dropped or placed on probation.

If in the opinion of the Faculty of the School concerned, a student's general record is unsatisfactory, the student may be refused permission to continue his course even though he has met the minimum requirements in respect to the number of hours of work passed and the grades in those hours. Students who fall behind in their work may be warned, put on probation, or dropped, either from an individual course or from the University, at any time during the term.

EMPLOYMENT AFTER GRADUATION

Graduates in chemical engineering find employment in the design, development, operation, and administration of chemical engineering plants. There is also some demand for men with chemical engineering training for technical sales work in the chemical industries and for editorial work on technical publications. Some graduates in chemical engineering continue their specialized training as graduate students in chemistry or chemical engineering to prepare for positions as research chemists or research engineers.

Graduates in metallurgical engineering are employed in the various industries engaged in the winning and refining of metals, in the foundry industry, and in industries in which the heat treatment, welding, and forming of metals are important. They have gone into research, development, production, and technical service, as well as graduate study.

CURRICULUM (B.Ch.E.)

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Chemistry 111, Introductory Inorganic Chemistry	3	3	0
	Chemistry 115, Inorganic Chemistry Laboratory	3	1	5
	Physics 115, Mechanics	3	3	2½
	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	English 111, Introductory Course	3	3	0
	Engineering 3117, Drawing and Descriptive Geometry	2	0	4
	Total	17		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 2	Chemistry 112, Introductory Inorganic Chemistry	3	3	0
	Chemistry 116, Introductory Chemistry Laboratory	3	0	6
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	English 112, Introductory Course	3	3	0
	Engineering 3118, Drawing and Descriptive Geometry	2	0	4
	Total	17		

In addition to taking the above courses, all freshmen must satisfy the University's requirements in physical education and military training.

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Chemistry 307, Introductory Organic Chemistry	3	3	0
	Chemistry 311, Organic Chemistry Laboratory	2	0	6
	Chemistry 224, Introductory Quantitative Analysis	4	2	6
	Engineering 5101, Introductory Chemical Engineering	2	2	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Total	17		
TERM 4	Engineering 1156, Applied Mathematics	3	3	0
	Chemistry 308, Introductory Organic Chemistry	3	3	0
	Chemistry 312, Organic Chemistry Laboratory	2	0	6
	Engineering 5102, Introductory Chemical Engineering	2	2	0
	Engineering 1151, Mechanics	3	3	0
	Physics 118, Physical Electronics and Optics	3	3	2½
	Public Speaking 101	3	3	0
	Total	19		

In addition to taking the above courses, all sophomores must satisfy the University's requirements in physical education and military training.

TERM 5	Chemistry 403, Introductory Physical Chemistry	3	3	0
	Chemistry 411, Physical Chemistry Laboratory	2	0	5
	Engineering 1152, Mechanics	3	3	0
	Engineering 5203, Chem. Eng. Technology	2	2	0
	Engineering 1255, Materials of Construction	3	3	0
	Engineering 5851, Chemical Microscopy	3 or 0	1	5
	Engineering 3253, Cost Accounting	0 or 3	2	2½
	Engineering 5303, Unit Operations of Chemical Engineering	3	3	0
	Total	19		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 6	Chemistry 404, Introductory Physical Chemistry	3	3	0
	Chemistry 412, Physical Chemistry Laboratory	2	0	5
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 5204, Chem. Eng. Technology	2	2	0
	Engineering 1256, Materials of Construction	3	3	0
	Engineering 3253, Cost Accounting	3 or 0	2	2½
	Engineering 5851, Chemical Microscopy	0 or 3	1	5
	Engineering 5304, Unit Operations of Chemical Engineering	3	3	0
	Total	19		
TERM 7	Engineering 5353, Unit Operations Laboratory	3	2	3
	History 165, Science in Western Civilization	3	3	0
	Engineering 1233, Materials Testing Laboratory	3	1	2½
	Engineering 5103, Chemical Engineering Thermodynamics	3	3	0
	Engineering 5711, Library Use	1	1	0
	Engineering 5745, Control of Engineering Processes	3	3	0
	Electives	3	—	—
	Total	19		
TERM 8	Engineering 5354, Unit Operations Laboratory	3	2	3
	History 166, Science in Western Civilization	3	3	0
	Engineering 5104, Chemical Engineering Thermodynamics	3	3	0
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 5701, Plant Inspections	1	—	—
	Electives	6	—	—
	Total	19		
TERM 9	Engineering 4932, Electrical Engineering	3	2	2½
	Engineering 5603, Chemical Equipment	2	2	0
	Engineering 5605, Chemical Plant Design	2	1	3
	Engineering 5503, Chemical Engineering Computations	2	2	0
	Engineering 5953, Senior Project	2	0	6
	Engineering 5746, Chemical Engineering Economics	3	3	0
	Electives	3	—	—
	Total	17		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 10	Engineering 4933, Electrical Engineering	3	2	2½
	Engineering 5504, Chemical Engineering Computations	2	2	0
	Engineering 5604, Chemical Equipment	2	2	0
	Engineering 5606, Chemical Plant Design	2	1	3
	Engineering 5954, Senior Project	2	0	6
	Electives	6	—	—
	Total	17		

Elective courses may be taken in any college of the University. The selection must be approved by the student's Adviser.

METALLURGICAL ENGINEERING CURRICULUM (B.Met.E.)

TERM 1	Chemistry 111, Introductory Inorganic Chemistry	3	3	0
	Chemistry 115, Inorganic Chemistry Laboratory	3	1	5
	General Physics 115, Mechanics	3	3	2½
	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	English 111, Introductory Course	3	3	0
	Engineering 3117, Drawing and Descriptive Geometry	2	0	4
	Engineering 3403, Fundamentals of Machine Tools	1	0	2½
	Total	18		
TERM 2	Chemistry 112, Introductory Inorganic Chemistry	3	3	0
	Chemistry 116, Introductory Chemistry Laboratory	3	0	6
	General Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	English 112, Introductory Course	3	3	0
	Engineering 3118, Drawing and Descriptive Geometry	2	0	4
	Total	17		

In addition to taking the above courses, all freshmen must satisfy the University's requirements in physical education and military training.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 3	Chemistry 224, Introductory Quantitative Analysis	4	2	6
	Chemistry 301, Engineering Chemistry (Organic)	2	2	0
	General Physics 117, Electricity and Magnetism	3	3	2½
	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Geology 712, Metallurgical Raw Materials	3	3	0
	Engineering 6111, Introductory Metallurgy	2	1	2
	Total	17		
TERM 4	General Physics 118, Physical Electronics and Optics	3	3	2½
	Engineering 1156, Applied Mathematics	3	3	0
	Engineering 1151, Mechanics	3	3	0
	Engineering 3253, Cost Accounting	3	2	2½
	Economics 107, Introduction to Economics	3	3	0
	Public Speaking 101	3	3	0
	Total	18		

In addition to taking the above courses, all sophomores must satisfy the University's requirements in physical education and military training.

TERM 5	Chemistry 403, Introductory Physical Chemistry	3	3	0
	Chemistry 411, Physical Chemistry Laboratory	2	0	5
	Engineering 1152, Mechanics	3	3	0
	Engineering 1255, Materials of Construction	3	3	0
	Engineering 5851, Chemical Microscopy	3	1	5
	Engineering 6501, Metallurgical Calculations	2	2	0
	Total	16		
TERM 6	Chemistry 404, Introductory Physical Chemistry	3	3	0
	Chemistry 412, Physical Chemistry Laboratory	2	0	5
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 1233, Engineering Materials Laboratory	3	1	2½
	Engineering 1256, Materials of Construction	3	3	0
	Engineering 6811, Introductory Metallography	3	1	5
	Total	17		

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 7	Engineering 5103, Chemical Engineering Thermodynamics	3	3	0
	Engineering 5711, Library Use and Patents	1	1	0
	Engineering 6203, Smelting and Refining	3	3	0
	Engineering 6253, Unit Processes in Metallurgy	3	1	2½
	Engineering 6311, Physical Metallurgy	2	2	0
	Engineering 6351, Physical Metallurgy Laboratory	3	1	5
	Electives	3		
	Total	18		
TERM 8	Engineering 6114, Metallurgy of Casting, Working, and Welding	3	2	2½
	Engineering 6204, Smelting and Refining	3	3	0
	Engineering 6254, Unit Processes in Metallurgy	3	1	2½
	Engineering 6312, Physical Metallurgy	2	2	0
	Engineering 6701, Plant Inspections	1	0	0
	Engineering 4931, Electrical Engineering	3	2	2½
	Electives	3	0	0
	Total	18		
TERM 9	Engineering 5745, Control of Engineering Processes	3	3	0
	Engineering 6221, Advanced Process Metallurgy	2	0	0
	Engineering 6953, Senior Project	2	0	6
	Engineering 4932, Electrical Engineering	3	2	2½
	History 165, Science in Western Civilization	3	3	0
	Electives	6	—	—
	Total	19		
TERM 10	Engineering 6602, Metallurgical Design	3	3	0
	Engineering 6954, Senior Project	2	0	6
	Engineering 4933, Electrical Engineering	3	2	2½
	History 166, Science in Western Civilization	3	0	0
	Electives	6		
	Total	17		

Elective courses may be taken in any college of the University. The selection must be approved by the student's Adviser.

OPTIONS IN CHEMICAL AND METALLURGICAL ENGINEERING

A student in chemical engineering or in metallurgical engineering may select his elective courses in any of several optional fields to provide somewhat more extensive training than is afforded by the required courses in the curriculum. The student may also, if he so desires, arrange his elective work to provide a cultural background broader than that given by the required courses. The selection of electives must be approved by the Class Adviser.

Those students in Chemical or Metallurgical Engineering who are interested particularly in the financial and administrative aspects of engineering may register jointly in the School of Chemical and Metallurgical Engineering and in the School of Business and Public Administration at Cornell during their fourth and fifth years and may then, by continuing in the School of Business and Public Administration for one additional year after receiving the first degree in engineering, be awarded the degree of Master of Business Administration or Master of Public Administration. In this way it is possible for a student to receive both the degree in engineering and the degree in business or public administration after a total period of residence of six years.

Opportunities for summer employment in chemical and metallurgical industries are increasingly available to students who have completed two or more years of their training.

The Graduate School of Aeronautical Engineering

THE PRIMARY objective of this School is the training of selected engineering and science graduates in the scientific aspects of aeronautics. This training is intended especially to prepare the students to carry out research and development engineering in the aeronautical and related industries and in aeronautical scientific institutions.

To this end, students are admitted to this School who have demonstrated, in their undergraduate careers, more than average abilities in analytical subjects, and who have shown adequate promise of carrying on graduate study successfully.

In the aeronautical engineering program, considerable emphasis is placed upon original research, both theoretical and experimental. Through the academic year, close contact is maintained between the Graduate School at the University and the Cornell Aeronautical Laboratory in Buffalo, N.Y. In addition, certain periods of employment at the Laboratory are offered to aeronautical engineering students—usually during their summer vacations. Students are urged to take advantage of such employment, if it is available. It is also possible that certain experimental equipment of the Laboratory will occasionally be available to graduate students in connection with their original research.

The Graduate School of Aeronautical Engineering is equipped with a fluid-mechanics laboratory on the campus in Ithaca for fundamental scientific research in fluid mechanics and aerodynamics.

ADMISSION

Application for admission to the Graduate School of Aeronautical Engineering as a candidate for the degree M.Aero.E. should be made directly to the Director of the Graduate School of Aeronautical Engineering, College of Engineering, Cornell University. A special application blank for this purpose can be obtained from the office of the Director. It should be sent to the Director of the Graduate School of Aeronautical Engineering.

The degree M.Aero.E. is awarded under the jurisdiction of the College of Engineering, and therefore candidates for this degree do not register in the Graduate School of the University.

Students who desire to work for the degree Ph.D. with aeronautical

engineering as their major subject must be admitted to the Graduate School of the University in the usual manner. They should make application to the Dean of the Graduate School, using the application blank for admission to the Graduate School.

CURRICULUM

The aeronautical engineering curriculum is planned to accomplish the broad objectives stated above. Courses of study are provided leading to the degree of Master of Aeronautical Engineering and to the degree of Doctor of Philosophy with aeronautical engineering as the major subject.

A. *Course of Study Leading to the Degree M.Aero.E.*

This program of aeronautical engineering studies is not only applicable to much of the standard engineering work in the aeronautical industry, but beyond that the course is planned to increase the student's facility in the use of the basic sciences in aeronautical engineering and to stimulate growth in the performance of independent research and development work. Because the progress in this field is so extremely rapid, it is an essential objective of this program to go beyond the study of present-day practices and techniques and to prepare the student in the fundamental background and analytical methods that can be adapted to future development.

(1) *The curriculum requirement* for the degree M.Aero.E. is the successful passing of a series of courses or examinations in these subjects. The list of subjects reproduced below constitutes a standard of accomplishment for the M.Aero.E. candidate, but the Faculty will modify the list to suit the needs, interests, and background of each individual candidate. Sufficient course offerings are available to permit candidates to study in any of three areas of aeronautical engineering: (1) aerodynamics, (2) gasdynamics (aerophysics), (3) aeronautical structures. Active research in all three areas is being carried out in the School.

Although the standard list of required subjects is such as ordinarily to occupy (together with the thesis) four terms of graduate study, the residence requirement has been set at one year (two terms), so that students who enter the School with exceptional preparation, or are able otherwise to pass the required examinations, may be able to qualify for the degree in one year.

When the student desires to satisfy a requirement by examination (rather than by passing a course), he should request the Faculty of the School to schedule such an examination.

It is suggested that each candidate supplement his required program of courses, e.g., the standard list below, by additional courses either in aeronautical engineering or in other fields of study, so as to result in a balanced program of twelve to sixteen credit hours per term.

(2) *An acceptable Master's Thesis,* based upon original research, is required of each candidate for the M.Aero.E.

(3) M.Aero.E. candidates must pass a *final examination,* either oral or both oral and written, administered by the Faculty of Aeronautical Engineering. The Faculty will frequently invite other members of the University staff to attend and to participate in such examinations.

Standard List of Required Subjects for M.Aero.E.

	CREDIT HOURS
Mathematics 611 and 612, Higher Calculus for Engineers and Physicists	6
or	
Engineering 1170 and 1171, Advanced Mechanics	6
Engineering 7101, Mechanics of Airplanes	3
Engineering 7102, Mechanics of Airplanes	3
or	
Engineering 7203, Aerodynamics of Power Plants	3
or	
Engineering 4991, Electronic Engineering	3
Engineering 7204, Gasdynamics	4
Engineering 7301, Theoretical Aerodynamics I	3
Engineering 7401, and 7402, Airplane Structures	6
Engineering 7403 and 7404, Airplane Design	2
Electives chosen from List A below	12

Electives: List A

Engineering 7206, Special Topics in Physical Gasdynamics	2
Engineering 7302, Theoretical Aerodynamics II (Wing Theory)	3
Engineering 7303, Theoretical Aerodynamics III (Compressible Fluids)	3
Engineering 7304, Theoretical Aerodynamics IV (Viscous Fluids)	3
Engineering 7305, Aerodynamics of Compressible Viscous Fluids	2
Engineering 7405, Aero-Elastic Problems	1
Engineering 7406, Special Methods of Structural Analysis	2
Engineering 3566, Combustion Theory	3
Engineering 1162, Mechanics of Vibration	3
or	
Engineering 1170, 1171, Advanced Mechanics	3, 3
Engineering 1163, 1164, Applied Elasticity	3, 3
Engineering 1165, Theory of Elastic Stability	3
Engineering 1167, Theory of Plates and Shells	3
Engineering 1168, Analogies in Boundary Value Problems	2
Engineering 1175, Introduction to Nonlinear Mechanics	3
Engineering 1181, Current Literature in Applied Mechanics	3
Engineering 1261, Plastic Behavior of Solids	3
Mathematics 621, 2, Mathematical Methods in Physics	4, 4
Mathematics 641, 2, Partial Differential Equations	3, 3
Physics 242, Analytical Mechanics	3
Physics 243, Atomic and Molecular Physics	3
Physics 475, Theoretical Mechanics	3
Physics 090, Special Laboratory Work	(arranged)

B. *Courses Leading to the Degree Ph.D.*

Students will be admitted to candidacy for the degree Ph.D. as set forth in the current *Announcement of the Graduate School.* General requirements such as residence, major and minor subjects, requirements in foreign languages, qualifying examinations, and thesis are also explained there. Each candidate is required to complete a schedule of courses acceptable to his Special Committee, as explained in the Announcement.

PREPARATION FOR GRADUATE STUDY

The Graduate School of Aeronautical Engineering will admit students holding baccalaureate degrees in any branch of engineering, physics, or mathematics, provided that their undergraduate scholastic records are such as to indicate ability to handle graduate study. The courses of study in engineering physics and in mechanical engineering (Option A) are especially recommended to students who expect to enter this School after graduation.

It will be possible for Cornell students in the five-year undergraduate programs to complete the requirements for the degree M.Aero.E. in one year of graduate study instead of the normal two years, if they complete a sufficient number of the required graduate courses as electives in their undergraduate programs. The following courses are recommended for this purpose:

Engineering 7101, 7102	Mechanics of Airplanes
Engineering 7203	Aerodynamics of Power Plants
Mathematics 611, 612	Higher Calculus for Engineers and Physicists
or	
Mathematics 621, 622	Mathematical Methods in Physics
Engineering 7204	Gasdynamics
Engineering 7401, 7402	Airplane Structures
Engineering 7403, 7404	Airplane Design
Engineering 1170, 1171	Advanced Mechanics
Engineering 1162	Mechanics of Vibration
Engineering 1165	Theory of Elastic Stability
Physics 242	Analytical Mechanics

To be admitted to graduate courses, an undergraduate student must

(1) be a regularly enrolled student in at least the seventh term of one of the engineering, physics, or mathematics curricula at Cornell University,

(2) show promise, by his previous scholastic record or otherwise, of ability satisfactorily to pursue advanced study and research, and

(3) have his admission to the courses recommended by the Director of

the Graduate School of Aeronautical Engineering (or the chairman of the department concerned) and approved by the Dean of the College of Engineering.

It is further recommended that all students who expect to enter the Graduate School of Aeronautical Engineering include in their programs the following courses, or their equivalents:

Mathematics 201	Differential Equations
Engineering 1155	Intermediate Mechanics
Engineering 1151, 1152, 1153	Mechanics and Strength of Materials
Engineering 3530	Thermodynamics

Department of Engineering Physics

OBJECTIVES

THE DEPARTMENT of Engineering Physics is a new department constituted so as to provide a type of education and training which will effectively bridge the gap between that of the basic sciences and that of conventional engineering practice. The general aim is to prepare students for a prospective career in technical research and advanced engineering development. As a result of the expanding technological activities in the country, the industrial research laboratories and engineering development laboratories are in urgent need of graduates with the vigorous and exacting course of study which the curriculum of this department provides.

FACULTY

The administrative arrangement of the Department is such that the Faculty of the Department includes members of the science departments of the College of Arts and Sciences and members of the several schools of engineering in the College of Engineering who are particularly interested in the objectives of the Department.

LABORATORY FACILITIES

The Department of Engineering Physics has a fully equipped laboratory of electron microscopy, including two large research type electron microscopes and equipment for research both on the instrument itself and on applications to problems in physics, chemistry, biology, and engineering materials. Facilities are also available for study in applied electron optics.

The Department also maintains a laboratory with much special equipment for the study of the elastic properties of single metal crystals, of elastometers, plastics, and similar materials, and of other phenomena related to the physics of the solid state.

In addition, students carrying out their project study have access to the other laboratories of the College of Engineering and to those of the College of Arts and Sciences as may be desirable.

CURRICULUM

The curriculum leading to the degree of Bachelor of Engineering Physics covers intensive study over a five-year period. The course of study is designed to combine the broad, basic, scientific and analytical training of the physicist with the knowledge of the properties of mate-

rials and the technological principles of the engineer. The subject matter falls into three main categories: fundamental science, namely, mathematics, physics, and chemistry; the properties and treatment of material; and engineering practice.

For training in research, the student terminates the course by carrying out a semi-research project in a special field of his own choice, under the direction of a Faculty member who is an authority in the selected field. There are a great variety of these special fields in physics and engineering. They include topics in electron physics, atomic and nuclear physics, physical optics, electron optics and applications including electron microscopy, X-rays and crystal structure, spectroscopy, engineering electronics, communications, electrical machinery, servomechanisms, ultra high-frequency generation and propagation, circuit analysis, elasticity and stress analyses, properties of materials, engineering mechanics, physical metallurgy, thermodynamics and heat transfer, aerodynamics, airplane structure, etc.

ELECTIVE COURSES

Considerable flexibility in the technical courses is provided in the last few terms of the curriculum to allow the student to advance in some technical fields beyond the level provided by the required courses as his interest in such fields develops. To permit this, at least eighteen hours are provided to cover the semi-research project and the technical electives which may be selected, with the permission of the student's Adviser, from the following subjects: physics, mathematics, chemistry, physical metallurgy, advanced mechanics and elasticity, fluid mechanics, aerodynamics, heat power, communications, industrial electronics, servomechanism theory, ultra high frequency. The choice will depend largely on the student's particular ability or interest.

By suitable selection of technical electives during his last two years of candidacy for the B.Eng.Phys. degree, the qualified student may obtain an unusually sound and well rounded education preparing him for a career in one of the many specialized fields of engineering. Here are two examples.

Aeronautical Engineering: A properly qualified student may elect courses given in the Graduate School of Aeronautical Engineering and thus obtain an excellent preparation in aeronautical engineering at the undergraduate level. Also, this procedure will shorten the time required to complete the requirements for the M.Aero.E. degree if the student wishes to continue study in that field. Details of this arrangement are described on page 64.

Atomic Power: It is possible to choose electives so as to provide a well rounded and extensive education for a career in the nuclear energy field or in nuclear reactor power developments. Courses in reactor physics,

in advanced heat transfer, and in physics of solids underlying radiation damage problems are available.

Members of the Faculty will assist the student in planning a special program in his particular field of interest.

The curriculum provides for a minimum of thirty hours of liberal courses. Of these, there are twelve hours required and eighteen hours to be elected. These electives may be chosen from the following subjects: astronomy, biology, botany, the classics, economics, English, fine arts, government, history, industrial and labor relations, literature, music appreciation, philosophy, psychology, sociology, speech. The opportunity thus afforded for contact with the broader phases of education offered by the University as a whole assists in expanding the student's mental horizon and in developing him as a well-rounded citizen.

Students who pass the proficiency examination of the Department of Modern Languages may substitute six hours of other liberal electives in place of the language requirement. Students who wish to continue the modern language studied in high school may take the College Board Achievement Test in that language; otherwise, they will be asked to take a proficiency examination at the University. Further information is given in the section on "Proficiency Requirements" in the *Announcement of the College of Arts and Sciences.* Students who show proficiency in the first term of the introductory course in English may be permitted, with the consent of the Department of English, to substitute other courses in English or English literature in the second term.

In addition, a maximum of nine hours of free electives is provided which may be chosen from any courses in the University which are open to the student, except, however, that not more than six credit hours toward the baccalaureate degree will be allowed in advanced military science and tactics or in naval science.

CLASS ADVISERS

Members of each entering class in the engineering physics curriculum are assigned to an Adviser who will counsel and supervise each student in matters connected wth choice of elective courses, registration, scholarship, and other matters of importance encountered during the student's entire college career. The personal relationship between the Adviser and the student and the Adviser's intimate knowledge of the student's academic performance can be of great help to the student in obtaining the best results from his university training.

SCHOLASTIC REQUIREMENTS

A student enrolled in the engineering physics curriculum is expected to maintain the following minimum scholastic requirements:

(1) receive a passing grade in every course for which he is registered,

(2) maintain each term a weighted average of at least 75%,

(3) exhibit natural aptitude and competence in the basic subject matter of the curriculum.

A student failing to satisfy these requirements may be put on probation or refused permission to continue his studies in the Department.

THE ENGINEERING PHYSICS CURRICULUM

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Chemistry	3	3	2½
	English 111, Introductory Course	3	3	0
	Engineering 3117, Drawing and Descriptive Geometry	2	0	5
	Liberal Elective	3	3	0
	Total	17		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Chemistry	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 3118, Drawing and Descriptive Geometry	2	0	5
	Engineering 3403, Fundamentals of Machine Tools	1	0	2½
	Elective	3		
	Total	18		
TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Engineering 1151, Statics	3	3	0
	A modern foreign language	6	2	6
	Engineering 6110, Casting, Working and Welding of Metals	2	1	2
	Total	17		
TERM 4	Mathematics 201, Elementary Differential Equations	3	3	0
	Physics 118, Electricity, Magnetism, and Light	3	3	2½
	Chemistry 402, Introduction to Physical Chemistry	3	3	0
	Engineering 1153, Mechanics of Materials	3	3	0
	Physics 208, Physical Mechanics and Properties of Matter	3	3	0
	Engineering 4983, Basic Electrical Engineering	4	3	2½
	Total	19		

In addition to these courses, students must satisfy the University's requirements in military training and physical education for the first four terms.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 5	Mathematics 613, Methods of Applied Mathematics	3	3	0
	Physics 225, Electricity and Magnetism	3	3	0
	Engineering 8121, Thermodynamics and Kinetic Theory	3	3	0
	Engineering 4116, Electric-Circuit Laboratory	3	1	3
	Elective	3		
	Total	15		
TERM 6	Mathematics 614, Methods of Applied Mathematics	3	3	0
	Physics 242, Analytical Mechanics	3	3	0
	Engineering 8122, Thermodynamics and Kinetic Theory	3	3	0
	Engineering 4121, Electron Tubes and Circuits	4	2	5
	Elective	3		
	Total	16		
TERM 7	Mathematics 615, Methods of Applied Mathematics	3	3	0
	Physics 243, Atomic and Molecular Physics	3	3	0
	Engineering 1201, Engineering Materials	3	3	0
	Engineering 4122, Electronic Circuit Elements	4	2	5
	Elective	3		
	Total	16		
TERM 8	Mathematics 616, Methods of Applied Mathematics	3	3	0
	Physics 254, Electronic Properties of Solids and Liquids	3	3	0
	Physics 210, Advanced Laboratory	3	0	5
	Engineering 1231, Engineering Materials Laboratory	3	1	2½
	Advanced Chemistry	3	3	0
	Elective	3		
	Total	18		
TERM 9	Physics 210, Advanced Laboratory	3	0	5
	Engineering 1202, Advanced Materials	3	3	0
	Engineering 8051, Project	3		
	Electives	9		
	Total	18		
TERM 10	Physics 258, Mechanics of Continuum	3	3	0
	Engineering 8052, Project	3		
	Electives	12		
	Total	18		

Agricultural Engineering

A JOINT program administered by the Colleges of Agriculture and Engineering leads to the degree of Bachelor of Agricultural Engineering. Students in this curriculum register in the College of Agriculture during the first four years but take courses in the Colleges of Engineering, Arts and Sciences, and Agriculture. Registration for the fifth and final year is in the College of Engineering, which grants the degree.

PURPOSES

The curriculum in professional agricultural engineering is to train engineers for agriculture in such fields as power and machinery, structures, electrification, soil and water management, and the processing and handling of farm products.

OUTLINE OF INSTRUCTION

The curriculum leading to the degree of Bachelor of Agricultural Engineering requires five years of study. Subject matter is drawn from five basic fields of study:

1. Basic science (mathematics, chemistry, physics, biology, bacteriology, geology)
2. Engineering science (mechanics, property of materials, thermodynamics, heat transfer, electrical theory)
3. Engineering application (structural design, hydraulics, surveying, power, machinery design, water control and management)
4. Agriculture (soils, field crops, livestock feeding, farm management)
5. General studies (English, history, public speaking, economics)

Students in this curriculum are required to meet the farm-practice requirement of the College of Agriculture (see the *Announcement of the New York State College of Agriculture*).

ADMISSION REQUIREMENTS

Requirements for entrance to this curriculum are the same as those for mechanical, civil, and electrical engineering. Since, however, it is the purpose of this curriculum to train engineers for agriculture, careful attention will be given to evidence of interest in and background for the work on the part of applicants.

CURRICULUM (B.Agr.E.)

(For a complete description of the courses in agriculture, see the *Announcement of the New York State College of Agriculture.*)

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 1	Mathematics 161, Analytic Geometry and Calculus	3	3	0
	Physics 115, Mechanics	3	3	2½
	Chemistry 105, General Inorganic Chemistry	3	2	3
	English 111, Introductory course	3	3	0
	Engineering 3111, Drawing and Descriptive Geometry	3	1	5
	Agriculture 1, Orientation	1	1	0
	Total	16		
TERM 2	Mathematics 162, Analytic Geometry and Calculus	3	3	0
	Physics 116, Wave Motion, Sound, and Heat	3	3	2½
	Chemistry 106, General Inorganic Chemistry	3	2	3
	English 112, Introductory Course	3	3	0
	Engineering 3112, Mechanical Drafting	3	1	5
	Agr. Engineering 2, Introduction to Agricultural Engineering	2	2	0
	Total	17		

In addition to taking these courses, all freshmen must satisfy the University requirements in physical education and in military training.

Farm practice is required. See the *Announcement of the New York State College of Agriculture.*

TERM 3	Mathematics 163, Analytic Geometry and Calculus	3	3	0
	Physics 117, Electricity and Magnetism	3	3	2½
	Chemistry 301, Organic Chemistry	2	2	0
	Engineering 1151, Mechanics—Statics	3	3	0
	Biology 1, General Biology	3	2	2½
	Geology 115, Elementary Geology	3	2	2½
	Total	17		
TERM 4	Physics 118, Electronics and Optics	3	3	2½
	Chemistry 402, Physical Chemistry	2	2	0
	Engineering 1152, Mechanics—Dynamics	3	3	0
	Engineering 1153, Strength of Materials	3	3	0
	Engineering 2116, Surveying (to be arranged)	3	3	2½
	Biology 1, General Biology	3	2	2½
	Total	17		

In addition to taking these courses, all sophomores must satisfy the University requirements in physical education and in military training.

		CREDIT HOURS	CONTACT HOURS LEC. REC.	LAB. COMP.
TERM 5	Engineering 1211, Materials of Construction	3	2	2½
	Engineering 2301, Elementary Fluid Mechanics	3	3	0
	Engineering 2701, Elementary Structural Analysis	3	2	2½
	Agronomy 1, Nature and Properties of Soils	5	5	2½
	Animal Husbandry 10, Livestock Feeding	4	3	2½
	Total	18		
TERM 6	Engineering 3341, Machine Design	4	3	2½
	Engineering 1212, Materials	3	2	2½
	Engineering 2302, Hydraulics	3	2	2½
	Agricultural Bacteriology 3	3	3	0
	Bacteriology Laboratory	1	0	4
	Electives	3	Arr.	Arr.
	Total	17		
TERM 7	Engineering 2704, Statical Indeterminate Struct.	3	3	0
	Engineering 3530, Heat Power Engineering	3	3	0
	Engineering 1155, Applied Mathematics	3	3	0
	Agronomy 11, Production of Field Crops	4	3	2½
	History 165, Science in Western Civilization	3	3	0
	Ext. Teaching 101, Oral and Written Exp.	2	2	0
	Total	18		
TERM 8	Engineering 3503, Heat Transfer	3	2	2½
	Agr. Engineering 221, Soils and Water Engineering	3	2	2½
	Agricultural Economics 102, Farm Management	5	3	3
	Economics 107, Introduction to Economics	3	3	0
	History 166, Science in Western Civilization	3	3	0
	Total	17		

Summer: six week term. #206. *Field Problems in Agricultural Engineering.* Credit 6 hours.

TERM 9	Engineering 3523, Refrigeration and Air Conditioning	2	2	0
	Engineering 4931, Electrical Engineering	3	2	2½
	Engineering 2715, Reinforced Concrete Design	3	1	5
	Agr. Engineering 202, Farm Power	3	2	2½
	Agr. Engineering 252, Seminar	1	Arr.	Arr.
	Elective	6	Arr.	Arr.
	Total	18		
TERM 10	Engineering 4932, Electrical Engineering	3	2	2½
	Agr. Engineering 231, Farm Structures Design	3	2	2½
	Agr. Engineering 203, Agricultural Machinery Design	3	2	2½
	Agr. Engineering 252, Seminar	1	Arr.	Arr.
	Elective	6	Arr.	Arr.
	Total	16		
	Total for ten terms	177		

Description of Courses

THE COURSES listed in the preceding curricula are described in the following sections of this Announcement. Courses are described under the heading of the school or college in which the course is offered. Courses in chemistry, English, mathematics, physics, and certain courses in economics are offered by the College of Arts and Sciences. Courses in military training and physical education, under the direct supervision of the University as a whole, are listed in a general section.

The courses designated by four digit numbers are offered by the College of Engineering. The first digit represents the school or department. Descriptions of courses will be found in the section of this Announcement as follows:

1. Engineering Mechanics and Materials
2. Civil Engineering
3. Mechanical Engineering
4. Electrical Engineering
5. Chemical Engineering
6. Metallurgical Engineering
7. Aeronautical Engineering
8. Engineering Physics

General courses of instruction required by some or all of the schools within the College of Engineering but given in other colleges of the University are described on pages 122-130, inclusive.

For courses in other colleges not described here, to be taken as electives, see the Announcement of the appropriate college.

ENGINEERING MECHANICS AND MATERIALS

Courses described in this section are given by the Department of Engineering Mechanics and Materials. They constitute a major part of the stem of basic engineering science prescribed for all engineering students and are directed toward the development of fundamental background for application to all phases of engineering work.

Advanced and graduate courses in these fields are also included in this section.

Messrs. CONWAY, CRANCH, CUYKENDALL, FAY, GUNDER, JEFFREY, HOWELL, MASON, MOYNIHAN, PERKINS, SACK, SLATE, STEG, STUART, and WIEGANDT.

1134. *MECHANICS OF ENGINEERING—STRENGTH OF MATERIALS.* Required of all civil engineering students. Credit three hours. Three recitations a week; prerequisite, 1153. Elastic curves, safe loads, columns, flexure of beams. Problems showing the application of engineering design.

1145. *APPLIED ENGINEERING MATHEMATICS.* Credit three hours. Three recitations a week. Prerequisites, Mathematics 163 and Mechanics 1134.

Elementary differential equations and their applications to engineering problems in the civil engineering fields. Analysis of numerical data and their graphical representation.

1151. *MECHANICS OF ENGINEERING—STATICS.* Credit three hours. Prerequisites, Physics 115 and parallel registration in Mathematics 163. The principles of statics of particles, chains, and rigid bodies. Equilibrium, friction, centroids, moments and products of inertia, virtual displacements, graphical methods, three dimensional trusses and frames. Vector methods.

1152. *MECHANICS OF ENGINEERING—DYNAMICS.* Credit three hours. Prerequisites, 1151, 1155. The principles of dynamics of particles and rigid bodies. Rectilinear, curvilinear, rotational and general plane motion of rigid bodies. Impulse-momentum, work-energy, virtual work. Vector methods. (The section of this course for civil engineering students is offered in the spring term only and does not require 1155 as a prerequisite.)

1153. *MECHANICS OF MATERIALS.* Credit three hours. Prerequisite, 1151. Stress and strain, tension, compression, and shear, riveted and welded joints, elementary beam theory, combined stresses, columns, strain energy, beams on several supports.

1154. *ADVANCED STRENGTH OF MATERIALS.* Credit three hours. Three recitations a week. Prerequisite, Course 1155. Strength, stiffness and stability of machine parts, disks, plates, shells, thick cylinders, straight and curved beams; principal stresses in two and three dimensions; fatigue and theories of failure.

1155. *APPLIED MECHANICS.* Credit three hours. Three recitations a week. Prerequisites, 1152 and 1153. The formulation and solution of problems, arising in mechanical engineering, which involve the use of elementary differential equations, and Fourier series. Emphasis is placed on numerical as well as analytical methods of solution.

1156. *APPLIED MATHEMATICS.* Credit three hours. Three recitations a week. Prerequisite, Mathematics 163. The formulation and solution of problems in chemical engineering involving ordinary and partial differential equations, graphical and numerical methods, and special functions.

1159. *ADVANCED MECHANICS LABORATORY.* Credit three hours. Two 2½ hour laboratories per week, as arranged. A course for graduate students; undergraduates must have the consent of the instructor. The course entails approximately six reports covering the following subjects: (1) Analysis and design of experiments, statistics of testing; (2) amplification and recording of information, frequency response of amplifiers and recording apparatus; (3) experimental stress analysis using SR-4 resistance strain gages, stress coat and photoelasticity; (4) variation of properties of materials with temperature, measurement, and control of temperature; (5) vibrations of rods, plates, shells, etc., analysis of vibrations; (6) at least one problem in the student's own special field.

1162. *MECHANICS OF VIBRATION.* Elective for graduates and qualified undergraduates. Credit three hours. Three recitations a week. Prerequisite, 1155 or equivalent. The characteristic phenomena of mechanical vibrations encountered in engineering and their quantitative investigation, illustrated by a group of typical vibrating systems. Representation of simple harmonic motion; combination of several simultaneous motions; simple cases of free and forced vibrations, with damping; resonance; principles of transmission and isolation of vibration; systems of variable mass and variable elasticity; systems with several degrees of freedom; vibrations of taut wires, bars, beams, rings, membranes, and plates; relation of vibration and noise; self-excited vibration; detection and measuring instruments; examples of diagnosis and preventive measures.

1163, 1164. *APPLIED ELASTICITY.* Elective for graduates and qualified undergraduates. Continuing two terms. Credit three hours each term. Spring and fall terms respectively. Three recitations a week. Prerequisite for 1163, permission of the instructor; for 1164, 1163 and 1170 or a basic knowledge of Fourier series. General analysis of stress and strain, Airey's stress functions in cartesian and polar coordinates, trigonometric and strain energy methods; torsion of bars of arbitrary section, stress in thick cylinders and disks; beams on elastic foundations; Castigliano's theorem, application to frameworks and rings. Steady state and transient problems in the dynamics of beams, plates, and structural members.

1165. *THEORY OF ELASTIC STABILITY.* Elective for graduates and qualified undergraduates. Credit three hours. Three recitations a week. Mathematical analysis of the conditions under which columns, beams, rings, tubes, thin plates, and thin curved shells may fail by general or local buckling. Applications to mechanical, civil, naval, and aeronautical structures.

1167. *THEORY OF PLATES AND SHELLS.* Credit three hours. Spring term. Three recitations a week. Prerequisite, 1155 or a knowledge of elementary differential equations and permission of the instructor. Historical introduction; differential equations for the deflection of a plate in cartesian and polar coordinates; methods of solution for cases of uniform and nonuniform thickness; Navier and Levy solutions for simply supported rectangular plate, rectangular plate with clamped edges; temperature stresses; the membrane method of Marcus and applications; strain energy of a bent and stretched plate, application to large deflection theory, Föppls methods. Symmetrical deformation of cylindrical shells, temperature stresses, pressure vessels; buckling under radial pressure and end thrust; deformation of shells without bending, conical, ellipsoidal, and toroidal shells.

1170. *ADVANCED MECHANICS.* Credit three hours. Fall term. Three recitations a week. Prerequisite, 1155. The formulation and solution of problems in engineering mechanics by vector methods, Lagrange's equations, generalized coordinates, Fourier series. Conservative systems.

1171. *ADVANCED MECHANICS.* Credit three hours. Spring term. Three recitations a week. Continuation of 1170. Nonconservative systems, energy methods, impact loads, operational methods.

1172. *SELECTED TOPICS IN ADVANCED MECHANICS.* Offered as required. Credit as arranged. Special studies in selected topics. Such topics as rocket theory and design and wave propagation have been offered, and these or others will be offered as required.

1175. *INTRODUCTION TO NONLINEAR MECHANICS.* Credit three hours. Spring term. Three recitations a week. Prerequisite, a knowledge of elementary ordinary differential equations. A study of the methods of analysis of the nonlinear electrical and mechanical systems frequently encountered in practice, including criteria for stability and a comparison between linear and nonlinear methods. Emphasis will be placed upon the discussion of a number of problems rather than upon the coverage of a broad field.

1176. *INTRODUCTION TO NONLINEAR MECHANICS II.* Credit three hours. Fall term. Three recitations a week. Prerequisite, 1175, or permission of the instructor. Continuation of 1175. Nonlinear ordinary differential equations of second and higher order. Introduction to nonlinear partial differential equations. Examples are taken from electrical engineering and the mechanics of continua.

1181. *ANALYSIS OF CURRENT LITERATURE IN APPLIED MECHANICS.* Open to graduate students only. Registration by permission of instructor

only. Credit three hours. Fall term. Three recitations a week. Special training in the critical analysis and interpretation of technical papers currently appearing in the field of applied mechanics. Evaluation of assumptions, procedures, and conclusions of such papers. The preparation of critical discussions.

1198, 1199. *PROJECT.* Total credit 6 hours. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of engineering mechanics. Hours of credit given for each course will depend upon the amount and quality of the work done each term.

1201. *ENGINEERING MATERIALS.* Credit three hours. Three lecture periods a week. Prerequisites, Chemistry 301 and 402. A lecture course treating the physical and electrical properties of engineering materials with special emphasis on the relation of these properties to the structure of the materials and to their forming, working, heat treatment, etc.

1202. *ADVANCED ENGINEERING MATERIALS.* Credit three hours. Fall term. Primarily for fifth-year students in engineering physics; others with consent of instructor. Discussion of a number of special topics in the field of engineering materials, such as plastic and rheological properties; dielectric and magnetic behavior; semiconductors, etc. Emphasis is given to the interpretation of the phenomena in light of modern theories in physics of solids and liquids, and current literature is included in the assignments.

1211. *MATERIALS OF CONSTRUCTION.* Required of all civil engineers. Credit three hours. Two recitations and one laboratory period a week. Prerequisites, 1153 and Chemistry 402. A study of the basic chemical and physical properties of various engineering materials including cast iron, wrought iron, steel, aluminum, magnesium, stone, brick, tile, and other building materials. Laboratory testing of these materials so conducted as to emphasize both the techniques of testing and the evaluation of fundamental material properties. Behavior of the material both as an isolated element and as a structural component. Tensile, compressive, torsional, shearing, and flexure tests.

1212. *MATERIALS OF CONSTRUCTION.* Required of all civil engineers. Credit three hours. One recitation and two laboratory periods a week. Prerequisite, 1211. Should be preceded by or taken concurrently with 2715. A continuation of 1211 with special emphasis on timber, cement, concrete, and elemental concrete structural members. Emphasis is placed upon the laboratory studies of the fundamental characteristics and behavior of the materials.

1215. *MATERIALS SEMINAR.* Elective. Open to specially selected seniors or graduate students. One to six hours credit. One 1-hour period a credit hour. Abstraction and discussion of technical papers and publications in the materials field.

1216. *STRUCTURE AND PROPERTIES OF MATTER.* Credit two hours. Fall term. Primarily for graduate students in any branch of engineering. Prerequisite, permission of the instructor.

1217. *ADVANCED CONCRETE.* Spring term. Credit optional; two hours for lectures only or three hours for lectures and laboratory. Prerequisite, 1212 or equivalent. Lectures and discussions on such topics as air entrainment, petrography, durability, chemical reactions, and properties of aggregates.

1221. *ENGINEERING MATERIALS.* Credit three hours. Two lecture periods and one recitation a week. Prerequisites, Physical Chemistry 402 or its equivalent. A lecture course in engineering materials dealing with the making, shaping and treating of metals and alloys and the effects produced thereby on their physical

and mechanical properties which govern their adaptability for specific service requirements. Following the development of the general principles involved, their specific application to iron and steel is examined and explained.

1222. *ENGINEERING MATERIALS.* Credit three hours. Three lecture periods a week. Prerequisites, 1221 and Organic Chemistry 301 or their equivalent. A lecture course continuing the work of 1221 as applied to high alloy steels, tool and die steels, cast irons, the nonferrous metals and alloys. The effects of corrosion and temperature on the properties of materials are discussed. Also studied are these nonmetallic materials: fuels and their combustion, refractories, cementing materials and concrete, wood, rubber, plastics, and lubricants.

1223. *ENGINEERING MATERIALS.* Credit three hours. Two lectures and one laboratory period each week. Prerequisites, Organic Chemistry, Chemistry 301, and Physical Chemistry, Chemistry 402. A study of the properties of ferrous and nonferrous metals and alloys, and nonmetallic materials such as cementing materials and concrete, plastics, wood, rubber, thermal and electrical insulating materials. Special attention will be given to electrical and magnetic properties. The laboratory will illustrate materials testing, including mechanical and eleectrical properties of these materials.

1231. *ENGINEERING MATERIALS LABORATORY—METALS AND ALLOYS.* Credit three hours. One lecture and one laboratory period each week. Prerequisites, 1221 and 1153. May be taken simultaneously with the latter course. Materials testing and the properties of metals and alloys. These types of tests with testing machines and strain measurement will be performed: tension, torsion, compression, bending, impact, fatigue, hardness, and ductility. The relation between the properties, structure, selection, inspection and use of metals and alloys will be shown by the following experiments: carbon steels, cast irons, heat treatment, nonferrous metals and alloys, metallography, spectrography, radiography, and magnaflux.

1232. *ENGINEERING MATERIALS LABORATORY—NONMETALLIC MATERIALS.* Credit three hours. One lecture and one laboratory period each week. Prerequisites, 1222 and 1231. Materials testing and the properties, composition, selection, and use of the following nonmetallic materials: oils and lubricants, fuels (solid, liquid, and gaseous), plastics, wood, cementing materials, and concrete.

1233. *ENGINEERING MATERIALS LABORATORY—MATERIALS TESTING.* Credit three hours. One lecture and one laboratory period each week. Prerequisites, 1255, 1256, and 1153. May also be taken simultaneously with the latter two courses. Materials testing and the determination of the properties of materials and their significance. Laboratory work includes the study of construction, use, and calibration of testing machines; the testing of representative materials in tension, torsion, bending, compression, impact, fatigue, creep, and hardness; magnetic, microscopic, and radiographic inspection; photoelastic methods; testing of lubricants; lubrication and bearing tests.

1251. *ENGINEERING MATERIALS RESEARCH.* Credit, from one to three hours, depending upon the hours of actual work, forty hours of work being equivalent to one credit hour. Prerequisites, 1231, 1232, or 1233, or consent of instructor. Open to a limited number of seniors and graduate students who have shown suitable proficiency in the required courses in materials laboratory or who have other suitable background to enable them to carry on special problems and investigations under the supervision of the staff.

1252. *APPLICATIONS OF ENGINEERING MATERIALS.* Credit three hours. Two lectures and one recitation period each week. Prerequisite, 1231. This

course covers the applications of physical metallurgy to problems in engineering and will deal with all processing operations including casting, mechanical working and heat treatment, and the subsequent inspection and use of ferrous and nonferrous metals and alloys. The significance and control of mechanical properties will be emphasized.

1253. *PHYSICS OF ENGINEERING MATERIALS.* Credit, from one to three hours, depending upon the hours of actual work, forty hours of work being equivalent to one credit hour. Prerequisites, 1231, 1232, and 1233. Open to a limited number of seniors and graduate students who have shown suitable proficiency in the required courses in engineering materials and physics to enable them, under staff supervision, to carry on special problems and investigations in the field of the physical properties of engineering materials and the application of physical methods to production control.

1255, 1256. *MATERIALS OF CONSTRUCTION.* Primarily for students in chemical and metallurgical engineering. Credit three hours each term. Two terms. Lectures. Prerequisites or parallel courses, Physical Chemistry 403, 404. An introductory presentation of the nature, properties, treatment, and applications of the more important metals and alloys, including extractive and physical metallurgy and behavior under service conditions. Nonmetallic materials, including refractories, cement, protective coatings, and plastics, are also discussed.

1261. *PLASTIC BEHAVIOR OF SOLIDS.* Primarily for graduate students; for undergraduates with the consent of the instructor. Credit three hours. Fall term. Phenomenological classification of plastic behavior; experimental procedures. Conditions for plastic flow; stress distribution and displacements, boundaries between plastically and elastically strained regions. Physical concepts of plasticity; single crystals and dislocations; relaxation phenomena; grain boundaries; mobility of molecules in plastics and elastometers; phenomena at transition points; chemical reactions.

1298, 1299. *PROJECT.* Total credit six hours. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of engineering materials. Hours of credit given for each course will depend upon the amount and quality of the work done each term.

CIVIL ENGINEERING

Required courses in the civil engineering curriculum given outside the College of Engineering are as follows:

Chemistry 105, 106, 301, 402 (pp. 124-125)
Economics 107. Introduction to Economics (p. 125)
Economics 203. Money, Currency, and Banking (p. 125)
English 111, 112. Introductory Course (p. 125)
Geology 113. Engineering Geology (p. 126)
History 165, 166. Science in Western Civilization (p. 126)
ILR 293. Survey of Industrial and Labor Relations (p. 126)
Mathematics 161, 162, 163. Analytic Geometry and Calculus (pp. 126-127)
Physics 115, 116, 113, 114 (pp. 127-128)

DESCRIPTIVE GEOMETRY AND DRAWING

Mr. JENKINS and others.

2001. *DRAWING.* Credit three hours. Fall term. A first course of elementary civil engineering drawing, emphasizing the fundamentals of the graphic language as used in engineering. Technical lettering, the use of instruments, orthographic projection, freehand and technical sketching, working drawings, and charts and graphs. Prints are made of many of the tracings.

2002. *DRAWING.* Credit three hours. Spring term. Prerequisite, 2001 or equivalent. Instruction and drill in the fundamental conceptions of descriptive geometry dealing with the graphic solution of advanced space problems. This course develops a firm grasp of the principles of projection and provides ample training in visualization. Practical civil engineering problems from the fields of topographic mapping, structural drafting, and cartography are included in the course.

2004. *ADVANCED DRAWING.* Elective for upperclassmen. Credit one to three hours. Either term. Problems in concrete, structural, topographical, highway, and sanitary drafting; engineering drawings, rendered in color, to enable the student to supplement ordinary drawings with artistic representations, so portrayed as to be readily intelligible to nontechnical persons.

2005. *CARTOGRAPHY.* Elective for upperclassmen. Credit three hours. Fall term. A study of the field of cartography, with particular attention to the principles of map projections, the conventions, scales, and construction of planimetric, topographic, and chorographic maps from survey notes and data from aerial photographs. A first course to combine photogrammetry and topographic surveying into a practical course on map making and interpretation. Some work will be done with cartograms, science maps, block diagrams, scale models, and globes.

2006. *MAP REPRODUCTION.* Elective for upperclassmen. Credit three hours. Spring term. The preparation of map manuscripts and models for reproduction by both photographic and mechanical methods of duplication. The various methods of map reproduction are studied, with sufficient general theory incorporated to afford an understanding of the principles involved. The selection, evaluation and organization of cartographic material from ground and aerial surveys into map editions will assure the proper procedure to adopt for local circumstances.

SURVEYING

Messrs. McNAIR, LYON, SPRY, and others.

2111. *ELEMENTARY SURVEYING.* Required of all civil engineering students. Credit two hours. Spring term. One recitation-lecture and one field computation, or mapping period a week. Use and care of steel tape, level, and transit; note keeping; fundamental surveying methods; measurements of lines, angles, and differences of elevations; areas and plotting.

2112. *ADVANCED SURVEYING.* Required of all civil engineering students. Credit three hours. Fall term. Two recitations and one field or computation period per week. Prerequisite, 2111. Elements of topographic, hydrographic, and geodetic surveying; map projections; elements of practical astronomy; city, land, and mine surveying.

2113. *ROUTE AND AERIAL SURVEYING.* Required of all civil engineering students. Spring term. Credit three hours. Prerequisite, 2112. One recitation and two field or computation periods per week. Theory and practice in photogrammetric methods including mapping and preliminary reconnaissance for a route location using aerial photographs and maps made therefrom; theory and practice in staking out route locations and relocations involving simple, transition, vertical curves; earthwork measurements and computations. About one third of the course

is devoted to photogrammetry, about one third to paper reconnaissance, curve theory, and earthwork computations, and about one third to field work associated with route locations.

2114. *SUMMER SURVEY.* (Topographic, Hydrographic, Route, and Geodetic Survey Camp.) Required of all civil engineering students, following the sophomore year. Credit five hours. Field and office work six days a week. Attendance for five weeks. Date of the beginning of the camp will be announced in the spring term. Prerequisite, 2113. Practical experience in surveying under field conditions. An extensive topographic survey with emphasis on transit-stadia and plane table-stadia methods is made, and the corresponding map is drawn. A hydrographic survey of Cayuta Lake is executed, and maps are made. A complete route survey is made including reconnaissance from aerial photographs, preliminary survey, paper location, and staking of the final line. All horizontal and vertical control surveys are executed according to present standards, including base-line taping, triangulation with repeating and direction type optical-reading theodolites, traverse with subtense bar, and precise leveling. Astronomic observations for azimuth and position are made and results computed. Each student takes part in all aspects of the work.

2115. *LEAST SQUARES: ADJUSTMENT OF OBSERVATIONS.* Elective for upperclassmen and graduate students. Credit three hours. Fall term. Two recitations and one computation period per week. The course is designed for students desiring to make experimental investigations. Studies are made of the principles of probability; precision of observations, the propagation of errors, and the application of the fundamental principles of least squares to typical surveying problems; criteria for determining the significance of results; and derivation of empirical formulae.

2117. *GEODETIC SURVEYING.* Elective for upperclassmen and graduates. Credit three hours. Lectures, reading, discussions, and laboratory work three periods a week. Prerequisite, consent of the instructor. Consideration of special problems in geodetic surveying; base line; triangulation; traverse; precise leveling; deflection of the plumb line; figure of the earth; determination of gravity; isostasy; magnetic properties of the earth. Subject to arrangement to meet the special needs of students.

2119. *MAP PROJECTIONS.* Elective for upperclassmen and graduate students. Credit three hours. One recitation and two laboratory periods a week. The theory of map projections. Construction of projections. Plane coordinate systems.

2120. *VERTICAL CONTROL.* Elective for upperclassmen and graduates. Credit three hours. Spring term. Prerequisite, 2113. Lectures, reading, and field work. The basic principles of establishing a geodetic sea-level datum and of performing barometric, trigonometric, spirit, and electronic leveling. A study of precision altimetry by the single-base, two-base, and leapfrog methods, including effects of instrumental, and meteorological conditions, time, and topographic positions. Brief study of new instruments and methods of trigonometric and spirit leveling including the electronic elevation meter and radar altimeter. Determination of economic relationships of vertical control methods to mapping scale particularly with respect to photogrammetric methods.

2121. *ELEMENTS OF PHOTOGRAMMETRY.* Elective for upperclassmen and graduates. Credit three hours. Fall term. Prerequisite, 2103. Lectures, recitation, and laboratory work. A study of both principles and practice of terrestrial and aerial photogrammetric mapping, including planning flights, control surveys, uncontrolled mosaics, radial-line control, simple stereo-plotting instruments, parallax distortions, graphical tilt determination, trimetrogen charting, and economics. Terrestrial and both vertical and oblique aerial methods are studied.

2122. *ADVANCED PHOTOGRAMMETRY.* Elective for seniors and graduates. Credit three hours. Spring term. Prerequisite, 2121. Lectures, reading, and laboratory work. An advanced study of photogrammetric principles including controlled mosaics, rectification, graphical, mechanical, and analytical space orientation. Readings and reports from current technical literature. The principles of many of the most recent photogrammetric plotters are studied together with the economic relation of these instruments to density of field control, office methods, and personnel.

2123. *SURVEYING AND MAPPING INSTRUMENTATION.* Elective for graduates. Credit three hours. Spring term. Prerequisite, 2121. Lectures and assigned reading. Independent study of some of the new developments in surveying, mapping, and photogrammetric instruments including a brief historical sketch of instrumentation, optical-reading levels and transits, electronic base line measurement, precision altimeters, sonar equipment, equiangulator, odograph, photomapping device, and stereoscopic plotters such as the Multiplex, KEK, Kelsh, Mahan, Twinplex, convergent photography, and others. Correlation of the principles of new instruments and methods in this rapidly developing field.

2131. *ELEMENTS OF SURVEYING.* For students other than those in civil engineering. Credit one hour. Either term. One two-and-a-half-hour period a week. Fundamentals of engineering measurements. Appreciation of observations and errors. Principles of recording data. Use of steel tape, level, and transit. Problems of particular interest to students in fields other than civil engineering.

2132. *SURVEYING.* Primarily for students in agricultural engineering. Credit three hours. Spring term. Two recitations and one field period per week. Fundamentals of engineering measurements. Appreciation of methods of observations and errors. Principles of recording data. Use of steel tape, level, transit, and plane table. Aerial mapping. Emphasis on problems common in agricultural engineering.

2142. *GEODETIC OR PHOTOGRAMMETRIC ENGINEERING RESEARCH.* Either term. Prerequisites will depend upon the line of work to be pursued. Special problems in least squares, reduction of triangulation, and photogrammetric surveying as may be arranged.

2143. *SEMINAR IN GEODESY OR PHOTOGRAMMETRY.* One to six hours credit. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the geodetic or photogrammetric field.

HYDRAULICS AND HYDRAULIC ENGINEERING

Messrs. BOGEMA, CHRISTENSEN, JORISSEN, LYON, PRIEST, and REID.

2301. *FLUID MECHANICS.* Fifth term. Credit three hours. Three recitations a week. Prerequisite, 1152. Fluid properties. Pressure and pressure intensity. Hydrostatics. Fluid flow concepts and basic equations. Dimensional analysis. Similitude. Laminar and turbulent flow. Flow in pipes. Flow in open channels. Flow around immersed bodies.

2302. *APPLIED HYDRAULICS AND HYDROLOGY.* Sixth term. Credit three hours. Two recitations and one laboratory period a week. Prerequisite, 2301. Application of fluid mechanics principles to hydraulic problems. Flow measurement. Hydraulic machinery. Oil hydraulic systems. Elements of hydrology.

2303. *ADVANCED HYDRAULICS.* Elective. Credit three hours. Fall term. Three lectures and recitations a week. Prerequisite, 2302 (or 2331). This course involves more detailed and extended theory and application than the first course.

Problems considered include stability of flotation, barometric leveling, fluids subject to acceleration, hydraulic similitude, water hammer, open channel flow, and hydraulic jump.

2304. *HYDRAULIC MEASUREMENTS.* Elective. Credit three hours. Fall term. Two lecture-recitation periods and one laboratory or computing period per week. Prerequisite, 2302. Extensive study of methods of flow measurement. Similitude. The general flow equation. Volumetric and weight measurements. Pressure and pressure intensity. Measurements of fluid velocity. Rate of flow measurements in pipelines by inferential flow meters, variable area meters, special methods. Open channel flow measurements by weirs, current meters, flumes. Measurements under special conditions. Graphical and analytical methods of analyzing data. Errors and tolerances.

2305. *HYDRODYNAMICS.* Elective. Credit three hours. Spring term. Three recitations a week. Prerequisites, 2302 (or 2331) and Differential Equations. Physical properties of fluids, equations of motion for nonviscous fluid, circulation, irrotational motion, conformal transformation, laboratory methods for determining flow nets, pressure distribution on submerged surfaces, vorticity, equations of motion for viscous fluid, separation, drag, turbulence, wave motion.

2306. *PUMPS AND TURBINES.* Elective. Credit three hours. Spring term. Two recitations and one laboratory or computation period a week. Prerequisite, 2302 (or 2331). Theory and characteristics of the hydraulic ram; reciprocating and centrifugal pumps; impulse, reaction, and propeller type turbines; selection and testing of hydraulic machinery.

2307. *FLOW IN OPEN CHANNELS.* Elective. Credit three hours. Two lectures and one computing period a week. Prerequisite, 2302. Uniform flow, gradually varied flow, rapidly varied flow, hydraulic jump, waves, transitions, bends, obstructions, steep slopes, spillways, energy dissipation, and hydraulic models.

2308. *HYDRAULIC MODELS.* Elective. Credit three hours. Spring term. One recitation and two laboratory or computing periods a week. Prerequisite, 2302. Theory and practical use of models in designing hydraulic structures.

2331. *FLUID MECHANICS.* Required for students in mechanical and electrical engineering. Credit three hours. Either term. Three recitations a week. Prerequisite, 1152. Statics, dynamics of fluid flow, law of continuity, energy equation, turbulence, flow of compressible fluids, impulse momentum relations, resistance of submerged bodies, lubrication, and hydraulic machinery. Several demonstration lectures are given to illustrate fluid mechanics principles. Text: *Elementary Fluid Mechanics,* Vennard.

2342. *HYDRAULICS RESEARCH.* Elective. Either term. Prerequisite, Course 2302 or its equivalent. The subject and scope of the investigations in experimental or theoretical hydraulics should be selected by conference at the beginning of the term if not previously arranged. It is permissible and often desirable for two students to work together on the same investigation. Written reports are required, but the text need not be typewritten in thesis style. These reports are kept by the department. In most cases it is necessary to arrange a definite schedule for work in the laboratory to avoid conflicts.

2343. *HYDRAULICS SEMINAR.* Elective. Open to seniors and graduate students. One to six hours credit. Abstraction and discussion of technical papers and publications in the hydraulic engineering field.

2403. *HYDRAULIC STRUCTURES.* Elective. Credit three hours. Spring term. Three lectures and recitation periods each week. Prerequisite, 2412. Discus-

sion of advanced problems related to hydraulic structures. Stress analysis in dams. Design of arch dams. Sedimentation. Spillways and river protection works. Channel transitions and controls. Hydraulics of locks.

2404. *WATER POWER.* Elective. Credit three hours. Fall term. Two lectures and one computing period each week. Prerequisite, 2302. History of water power development; hydrologic, hydraulic, and geologic studies of water power sites; power output of streams; selection of turbines, power plant layout, and equipment; economic considerations; and preparation of engineering reports on water power development. Problems cover determination of available power, selection of turbines, use of pondage and storage, development of load curves, and determination of annual power output.

2406. *FLOOD CONTROL.* Elective. Credit three hours. Fall term. Two lectures and one computing period each week. Prerequisite, 2412. Analysis of general flood control problems; application of flood formulas; determination of design flood criteria; comparison of flood control methods; review of typical flood control projects; study of methods for determination of flood damage; economic analysis of proposed projects; and methods of operation during flood periods. Problems include determination of design floods by unit hydrograph methods; the routing of floods down natural channels; determination of levee locations; capacity of flood channels, and amount of storage required.

2410. *EROSION AND SEDIMENTATION.* Elective. Seniors and graduates. Credit three hours. Either term. Prerequisites, 2412, Engineering Geology 113. The hydraulic engineering aspects of erosion, sediment transportation, and deposition are included. The factors, such as type of soil, slope of land surface, intensity and duration of precipitation, land use, and land cover, that affect the amount of erosion; the principles governing sediment transportation, such as the quality and quantity of sediment entering the stream, and the capacity of the stream to transport such material; the methods of measuring the quantity and quality of sediment in streams and of sediment in reservoirs, the problems of sedimentation encountered in irrigation, flood control, and navigation of rivers and harbors; the characteristics of important sediment-laden streams.

2411. *RIVERS AND HARBORS.* Elective. Credit three hours. Fall term. Prerequisites, 2302 and 2412. Rivers: regimen of flow in natural streams; flood waves; transportation of sediment; channel improvement and protection; dams and locks; model studies. Harbors: gravity waves; harbor improvement; sea and shore relationships; shore improvement; model studies.

2412. *HYDRAULIC ENGINEERING.* Seventh or eighth term. Credit three hours. Three lecture-recitation periods a week. Prerequisite, 2302. Introduction to hydraulic engineering problems. Purpose, planning, and component parts of hydraulic projects. Flood routing. Ground water hydraulics. Reservoirs. Dams, spillways, and river protection works. Flumes and channels. Conduits, tunnels, penstocks. Locks. Hydraulic model studies.

2442. *HYDRAULIC ENGINEERING RESEARCH.* Elective. Graduate students. Either term. Prerequisite, 2412 and one additional elective course in field of selected research. Subject and scope of investigation to be undertaken is selected by conference at beginning of term. Preparation of extensive bibliography after extended search of available literature; extraction of pertinent data from all available sources; construction and operation of hydraulic laboratory models; and preparation of concise summary report covering selected investigation.

2443. *HYDRAULIC ENGINEERING SEMINAR.* Elective. Seniors and graduate students. Credit one to six hours. Either term. Discussion of selected topics in the hydraulic engineering field.

SANITARY ENGINEERING

Messrs. GATES, GIFFT, and LYNCH.

2501. *MICROBIOLOGY IN ENGINEERING.* Required of all students in civil engineering. Credit three hours. Two lecture recitations and one laboratory a week. Prerequisite, Chemistry 106. Introduction to the nature, characteristics, and activities of microorganisms and their effect on man and his environment, including their roles in the transmission of disease, in the cycles of the elements of nature, in the aerobic and anaerobic decomposition of organic and inorganic material, and in industrial applications and processes.

2502. *WATER SUPPLY AND TREATMENT.* Required of all students in civil engineering. Credit three hours. Two recitations and one computing period a week. Prerequisites, 2301, 2501. Sources of water supply, quantity available, uses, and rates of demand. Quality, examination, treatment, and purification. Collection, storage, pumping, and distribution systems. Laboratory periods will include examination and reports on water supply systems, design problems, and cost estimates.

2503. *SEWERAGE AND SEWAGE TREATMENT.* Required of all students in civil engineering. Elective for chemical engineering students. Credit three hours. Either term. Two recitations and one computing period a week. Prerequisites, 2301, 2501. The design of sanitary and storm sewers and the methods of treating sewage are considered in the recitations; in the computing period, problems are assigned dealing with design and operation and with subject matter considered in recitation and classroom work. The problems are largely of the nature of separate designs.

2504. *SANITARY BIOLOGY.* Required of graduate students who have not had 2501 or its equivalent. Credit three hours. Two lectures, one laboratory, plus special assignments. Either term. Fundamentals and methods of microbiology with emphasis on water bacteriology and aquatic biology. The nature and control of microorganisms associated with water quality and treatment and the biology of self-purification and of waste treatment processes.

2506. *ADVANCED WATER SUPPLY.* Elective for seniors and graduates. Credit three hours. Spring term. Two recitations and one computation period a week. Prerequisite, 2502. A comprehensive study of the general principles and methods involved in furnishing safe water supplies of satisfactory quality. Water treatment methods, such as coagulation, sedimentation, aeration, slow and rapid sand filtration, taste and odor control, softening and iron removal, corrosion control, sterilization, and miscellaneous treatment methods. Also, some study of design and operation of water treatment plants.

2507. *ADVANCED WASTES TREATMENT.* Elective for seniors and graduates. Credit three hours. Fall term. Two recitations and one computation period a week. Prerequisite, 2503. A comprehensive study of principles and methods involved in the design, construction, and operation of sewage treatment works, including reference to existing typical plants. The disposal of sewage by dilution; stream pollution and self-purification; sewage treatment methods, including preparatory devices, sedimentation, chemical precipitation, intermittent sand and trickling filters, activated sludge, sludge digestion, sludge dewatering and incineration, and miscellaneous treatment methods.

2508. *INDUSTRIAL WASTES.* Elective for seniors and graduates in civil engineering and for chemical engineers. Credit three hours. Fall term. Three lectures or recitations a week. Prerequisite, 2503. The treatment of industrial wastes such as wastes from tanneries, packing houses, mines, canning factories, textile mills,

paper and pulp mills, creameries, cheese factories, condenseries, breweries, sugar refineries, etc. Special attention to experimental studies of waste treatment and to plant-scale treatment. Numerous references, bulletins, reports.

2509. *PUBLIC HEALTH AND COMMUNITY SANITATION.* Elective for advanced and graduate students in civil engineering and students outside the School by permission of the instructor. Credit three hours. Spring term. Three recitations or lectures a week. M W F 9. A general course outlining basic principles in transmission of disease and communicable disease control; organization and functions of federal, state, and local health departments; standards of environmental sanitation including water supply, waste disposal, milk, restaurant and school sanitation; insect and rodent control; industrial hygiene; vital statistics. Course adjusted to the needs of the students enrolled to demonstrate the responsibility of the individuals and their professions for maintaining the public health.

2511. *SANITARY ENGINEERING LABORATORY.* Credit three hours. One lecture-discussion and two laboratory periods a week. Prerequisites, 2502, 2503. The application of physical, chemical and bacteriological principles, methods, and procedures to the analysis and treatment of water, sewage, and industrial wastes. Laboratory scale study of water and sewage treatment processes; interpretation and application of these laboratory data to the design and operation of treatment processes and units.

2532. *MUNICIPAL SANITATION.* For students in city and regional planning or business and public administration. Elective for other advanced and graduate students. Credit three hours. Fall term. Lectures, reports, field trips. Three periods a week. The principles of water supply, disposal of wastes, and community sanitation as related to municipal and regional problems, from the standpoint both of planning and operation. Economic and legal problems in connection with industrial wastes and stream pollution control programs.

2541. *PROJECT.* Elective. Credit three hours. Either term. Should be preceded by 2502 and 2503 or equivalent courses. Methods of determining the capacity, basis of design, computations, sketches, and general plans involved in the design of sewerage, industrial waste, and water treatment works. Problems may be elected such as the design of a separate or combined sewerage system, an intercepting sewer, a municipal or an institutional sewage treatment plant, a plant for the treatment or disposal of an industrial waste, or a plant for the treatment of an industrial, institutional, or municipal water supply.

2542. *SANITARY ENGINEERING RESEARCH.* Either term. Prerequisites will depend upon the particular problem to be pursued, but in general should include work in water analysis, bacteriology, and courses in hydraulics and sanitary engineering dealing with the field in which the work is to be undertaken. Hours, credit for work, prerequisites, and other questions relating to contemplated research in this field will be arranged by conference.

2543. *SANITARY ENGINEERING SEMINAR.* Elective. Open to specially selected seniors or graduate students. One to six hours credit. Abstraction and discussion of technical papers and publications in the sanitary field.

TRANSPORTATION ENGINEERING

Messrs. BELCHER, HEWITT, and LEWIS.

2602. *TRANSPORTATION.* Required of all students in civil engineering. Credit three hours. Lectures and recitations three hours a week. Prerequisite, Economics 107 or consent of the instructor. The historical economic, regulatory,

construction, and operational aspects of transportation. Designed particularly for engineering students.

2610. *HIGHWAY ENGINEERING.* Required of all civil engineering students. Credit three hours. Two lectures, one computing period or field assignment each week. Prerequisite, 2113, and preceded by or taken concurrently with 2725. Design, construction, and maintenance of highways and city streets. Location and alignment (aerial photographic methods included), width, capacity, and geometrical design based on traffic demands. Drainage, soils, stabilization, aggregates. Bituminous materials. Structures, traffic control, landscaping. Economics and administration. Construction methods and equipment for grading and paving of low cost, flexible, and rigid pavements. Analysis and correction of characteristic pavement failures.

2612. *HIGHWAY LABORATORY—BITUMINOUS.* Elective. Qualified fourth and fifth year students and graduates. Credit three hours. Spring term. Two laboratory periods and seminar each week. Prerequisite, 2610, or may be taken concurrently with 2610. Bituminous materials are tested and aggregates studied for their compatibility with bitumens. Mixes are designed and tested for stability. Condition surveys are made on various classes of bituminous pavements, and field patching is executed. Laboratory fully equipped for all phases of applied and research studies.

2613. *HIGHWAY LABORATORY—STABILIZATION.* Elective. Qualified fourth and fifth year students and graduates. Credit three hours. Fall term. Two laboratory periods and seminar each week. Prerequisites, 2725 and 2610, or may be taken concurrently with 2610. Evaluation of current soil stabilization practices. Correlation of field and laboratory compaction procedures. Freeze-thaw and strength tests on soil samples stabilized with bituminous materials, Portland cement, and chemicals. Condition surveys are made on stabilized roads. Laboratory fully equipped for all phases of applied and research studies.

2614. *HIGHWAY DESIGN—STRUCTURAL.* Elective. Qualified fourth and fifth year students and graduates. Credit three hours. Fall term. Three lecture-recitation periods each week. Prerequisite, 2610, or consent of the instructor. Part I: Soil index properties and highway soil classification systems; surveying and sampling; subgrade evaluation, including field and laboratory CBR; subgrade modulus; compaction, drainage and frost action; stabilization; aggregates. Part II: Design and construction of base and surface courses for flexible pavements. Part III: Design and construction of rigid pavements.

2615. *HIGHWAY DESIGN—GEOMETRIC.* Elective. Qualified fourth and fifth year students and graduates. Credit three hours. Spring term. One lecture and two design periods each week. Prerequisite, 2610, or consent of the instructor. Route selection; design controls and criteria, including vehicle characteristics and highway capacity; sight distance, and horizontal and vertical control; cross section elements; right-of-way problems and access control; at-grade intersection design, including rotary and channelized intersection; grade separations and interchanges; regional systems of highways, freeways, and parkways.

2617. *AIRPORT ENGINEERING.* Elective. Qualified fourth and fifth year students and graduates. Credit three hours. Spring term. Two recitations and one computing period a week. Prerequisites, 2610 and 2725. The location, design, construction, and maintenance of airports.

2618. *LOW-COST ROADS.* Elective. Primarily for foreign students. Credit three hours. Taught whenever demand is sufficient. Prerequisite, 2610 or its equivalent. Study of economic importance of routes and selection of (farm-to-market) roads to be improved; location and design; subgrade soils and stabilization of subgrade soils by use of admixtures, chemicals, and bituminous materials;

drainage structures; bituminous treatments and bituminous mats for stabilized subgrades. Survey of the experimental work in the use of materials and design and construction of low-cost roads.

2619. *TRAFFIC ENGINEERING—OPERATIONS.* Elective. Qualified fourth and fifth year students and graduates. Credit three hours. Two laboratory periods and seminar each week. Prerequisite, preceded by or taken concurrently with 2620. Definition of traffic problems; collection of field data; analysis of field data; findings, conclusions, and recommendations. Traffic surveys. Design of traffic control systems.

2620. *TRAFFIC ENGINEERING.* Elective. Qualified fourth and fifth year students and graduates. Credit three hours. Two recitations and one computing period a week. Prerequisite, 2610. City and highway traffic surveys. Accidents, congestion, delay, speed, volume, density, parking, channelization, lighting, traffic control and routing. Signs, signals, and markings. Regulation; truck and bus units as traffic elements. Urban traffic consideration in city planning. Driver reactions and habit pattern; design of safety features and effectiveness of signs.

2621. *ANALYSIS AND INTERPRETATION OF AERIAL PHOTOGRAPHS.* Preregistration required. Elective. Credit three hours. Two lectures and one laboratory each week. (The student is expected to pay the cost of field trips and aerial photographs for use in a term project, which amounts to approximately $10.) A study of the soil and rock areas of the United States and the patterns that they present in aerial photographs. Fundamental elements of soil patterns are analyzed to permit determination of soil texture, type of bedrock, and drainage properties. Field training in selected test areas. Emphasis is placed on interpretation for engineering, regional planning, and agricultural purposes.

2622. *ADVANCED INTERPRETATION OF AERIAL PHOTOGRAPHS.* Preregistration required. Elective. Credit three hours. Organization of course depends upon fields of interest. Special problems: four each on ground water, engineering projects, agricultural soils mapping, and irrigation.

2641. *PROJECT, TRANSPORTATION ENGINEERING.* Elective. Credit three hours. Either term. Projects in the various fields of transportation, advanced aerial photographic studies, and traffic engineering may be developed by conference between professors and students. Projects may involve integrated planning or design drawing upon several fields of interest, or they may concentrate upon special subjects. Adequate facilities, material, and sources of data are necessary to a satisfactory project.

2642. *TRANSPORTATION ENGINEERING RESEARCH.* Qualified fourth and fifth year students and graduates wishing to pursue one particular branch of transportation engineering further than can be done in any of the regular courses may elect work in this field. The work may be in the nature of an investigation of existing methods or systems, theoretical work with a view to simplifying present methods of design or proposing new methods, or experimental investigation of suitable problems.

2643. *TRANSPORTATION ENGINEERING SEMINAR.* Elective. Open to selected seniors or graduate students. Credit one to six hours. Either term. Number of meetings a week to be arranged. Abstraction and discussion of selected technical papers and publications in the transportation engineering field.

STRUCTURAL ENGINEERING

Messrs. BIJLAARD, FISHER, GURALNICK, HOUGH, MASON, McGUIRE, WINTER, ZETLIN, and ZUK.

2701. *ELEMENTARY STRUCTURAL ANALYSIS.* Required of all civil engineering students. Credit three hours. Two recitations and one problem period a

week. Prerequisite, 1153. A first course in structural theory. Determination of reactions and internal forces and moments in beams, girders, trusses, and three-hinged arches due to stationary and moving loads. Use is made of graphical and analytical methods and of influence lines.

2702. *STEEL AND TIMBER STRUCTURES.* Required of all civil engineering students. Prerequisite, 2701. Three two-and-a-half hour periods a week. Analysis and design of steel members and connections. Design of welded and riveted roof trusses. Design of steel railway girder bridge. Characteristics, properties, and mechanics of timber. Partial design of segmental-member timber-roof trusses.

2704. *STATICALLY INDETERMINATE STRUCTURES.* Required of all civil engineering students. Credit three hours. Three lectures a week. (*Note:* Students intending to take elective courses in Structures in the ninth and tenth terms should register for this course in their eighth term.) Prerequisite, 2701. Deflections. Classical and modern methods of analysis of statically indeterminate beams, frames, trusses. Approximate and wind analysis. Introduction to model analysis. Use of influence lines in design.

2706. *ADVANCED STEEL DESIGN.* Elective for seniors and graduates. Credit three hours. Three two-hour periods a week. Prerequisite, 2713 or the equivalent. Critical study of current specifications for the design of steel buildings. Study of steel framing systems in current use. Problems in the analysis and design of commercial and industrial buildings.

2709. *ADVANCED STRUCTURAL ANALYSIS.* Elective for graduate students. Advanced undergraduate students by special permission. Credit three hours. Three periods a week. Prerequisite, 2704, or satisfactory examination. Review and critical comparison of fundamental methods for the solution of statically indeterminate structures and extension to more involved problems. Column analogy, members of variable cross-sections, curved beam and arch analysis, torsional moment-distribution, rigid space frames, shear distortion effects. Use of influence lines, numerical methods and model analysis for design. Design problems.

2710. *STRENGTH OF STRUCTURES.* Elective for graduate students and advanced undergraduate students. Prerequisite, 2704 (can be taken concurrently). Credit three hours. Three recitations a week. Analysis of two- and three-dimensional stress and strain. Theories of failure of ductile and brittle materials. Strain energy methods applied to bending, shear, buckling, and impact. Structural materials under load, strain hardening, residual stresses, hysteresis, stress concentration, alternating stress. Design for fatigue. Stresses beyond the elastic limit. Plastic or ultimate design of steel and reinforced concrete structures. Critical discussion of current design specifications.

2711. *BUCKLING OF STRUCTURES.* Elective for graduate students. Advanced undergraduate students by special permission. Prerequisites, 2710 and 1145 or equivalent. Credit three hours. Three recitations a week. Analysis and design involving elastic stability. Determination of buckling loads and maximum stresses of columns with and without initial crookedness and eccentricity. Solid and open web columns with variable cross-section. Beam columns. Lateral strength of unbraced beams. Buckling loads and ultimate strength of thin, compressed plates. Design of thin-walled steel structures. Critical discussion of current design specifications.

2713. *STRUCTURAL DESIGN.* Required of all civil engineering students. Credit three hours. Three problem periods a week. Prerequisites, 2702, 2704, 2715, 2720. Mechanical properties of steels and nonferrous metals as related to structural design. Strain hardening, stress concentration, fatigue. Technology, properties, and effects of welding. Planning and design of representative portions of complete

structural projects (framed buildings, bridges, other structures). Integrated use of basic design procedures presented in preceding courses.

2715. *REINFORCED CONCRETE DESIGN.* Required of all civil engineering students. Credit three hours. Either term. One lecture and two problem periods a week. Prerequisite, 2704 (can be taken concurrently). A first course in reinforced concrete. Elementary theory of reinforced concrete is applied to rectangular slabs, T-beams, beams reinforced for compression, columns, and footings. Shear, diagonal tension, and direct stress combined with flexure are treated. Several design reports are required which include reinforcement drawings, schedules, and formwork.

2716. *ADVANCED REINFORCED CONCRETE DESIGN.* Elective for seniors and graduate students. Credit three hours. Three two-hour periods a week. Prerequisite, 2715. Design problems in combined footings, retaining walls, comparative floor systems, flat slab building, highway bridge, single-span fixed arch. Discussion of prestressed concrete design procedures and plastic theory concepts of concrete design.

2717. *BRIDGE DESIGN.* Elective for graduate students and qualified seniors. Credit three hours. Prerequisites, 2704, 2715. Design of more complex types of steel and concrete bridges, such as continuous truss, multiple box culvert, rigid frame, arch. Basic planning of bridge project and study of problems common to all types of bridges, including substructures. Attention is given to traffic, hydraulic, and economic requirements, and use of field data, preliminary surveys, and model studies.

2718. *PRESTRESSED CONCRETE.* Elective. Credit three hours. Properties of material used in prestressed concrete. Creep of concrete. Prestressing methods. Design of statically determinate prestressed members. Ultimate strength and factors of safety. Discussion of statically indeterminate systems. Application of prestressing to complete structures.

2719. *ENGINEERING PLASTICITY.* Elective for graduate students. Prerequisites, 2710 and 1145 or equivalent. Credit two hours. Two recitations a week. Plastic behavior as based on crystalline structure. Brittle v. plastic behavior. Mechanism of plastic deformation and plasticity condition. Flow lines. Application to strength of metal structures and geophysics. Plastic buckling of columns and plates.

2720. *FOUNDATIONS.* Required of all civil engineering students. Credit three hours. Two lectures and one computing period a week. Prerequisites, 2715, 2725. Study of the structural problems encountered in foundation work. Retaining walls, sheet piling, spread footings, piles, piers, abutments, cofferdams, caissons, underpinnings. Design problems. Introduction to geophysical exploration and foundation vibrations.

2725. *ELEMENTS OF SOILS ENGINEERING.* Required of all students in civil engineering. Credit three hours. Either term. Two lectures and one laboratory period a week. Prerequisites, Geology 113, 1153, 2301. The elements of the formation and composition of soil, its fundamental properties, and its behavior as an engineering material. Instruction in principles of soil identification and classification, basic terminology and soil characteristics such as gradation, permeability, compressibility, consolidation, and shearing strength with applications to simple problems of seepage, settlement, bearing capacity, stability of earth slopes. Theory of lateral earth pressure. Discussion of methods and equipment for soil exploration. Laboratory tests for experimental determination of above mentioned soil characteristics and evaluations and use of data.

2726. *SOILS ENGINEERING THEORY.* Elective for seniors and graduate students. Credit three hours. Fall term. Three lectures a week. Prerequisite, 2725. Principles of mechanics and strength of materials relating to typical soils engineering problems and the fundamental physical and chemical characteristics of soil which

affect their application. Methods for determining the distribution of stresses induced in semi-infinite soil masses by surface and body forces, vibration of stress at a piont, and the Mohr theory of rupture. Composition, structure, and stress-strain characteristics of soil. Calculation of the amount and rate of settlement of structures, the stability of earth slopes and of embankment foundations. Basic principles of flow of water through soil, flow net construction, rate of seepage, and effect of seepage on stability of structures. Lateral earth pressure theory.

2727. *APPLIED SOILS ENGINEERING.* Elective for seniors and graduate students. Credit three hours. Spring term. Two lectures and one long period a week. Prerequisite, 2726. Application of soils engineering theory to problems. Planning and conduct of subsurface investigations for various types of work, determination of significant physical and chemical soil characteristics by test or other means, including appropriate laboratory exercises, analysis of actual designs of proposed structures for prediction of settlement, stability, rate of seepage or other service requirements, methods of inspection and control of earthworks construction, selection and placement of materials, compaction and stabilization.

2731. *ELEMENTS OF STRUCTURAL ENGINEERING.* Elective for students not in civil engineering. Credit two hours. One lecture and one computing period a week. Analysis and design of structural members and connections: steel, timber, reinforced concrete, simple foundations.

2741. *PROJECT.* Elective. Either term. Prerequisites, 2702, 2703, and 2715. The student may select a design problem such as the following: (a) an arch bridge, (b) a cantilever bridge, (c) a rigid frame bridge, (d) a special problem in steel or concrete building design, (e) the design of any other structure of particular interest to the student provided he has had the proper preparation for such design. The work is submitted in the form of reports. Drawings of typical details must accompany reports.

2742. *STRUCTURAL ENGINEERING RESEARCH.* Any term. Students wishing to pursue one particular branch of structural engineering further than can be done in any of the regular courses may elect work in this field. The prerequisite courses depend upon the nature of the work desired. The work may be in the nature of an investigation of existing types of construction, theoretical work with a view to simplifying present methods of design or proposing new methods, or experimental investigation of suitable problems.

2743. *STRUCTURAL ENGINEERING SEMINAR.* Elective. One to six hours credit. Open to specially selected seniors or graduate students. Preparation and presentation of topics of current interest in the field of structures for informal discussion.

2744. *SPECIAL TOPICS IN STRUCTURAL ENGINEERING.* Elective. Either term. Study in one or more of the specialized topics of civil engineering such as tanks and bins, suspension bridges, towers, or movable bridges, which are not covered in the regular courses. Independent design or research projects may also be selected.

SPECIAL AND GRADUATE COURSES

2801. *THESIS.* Elective. Seniors. Credit three or more hours. Either or both terms. The thesis gives the student an opportunity to work out a special problem or to make an engineering investigation, to record the results of his work, and to obtain academic credit for such work. Registration for thesis must be approved by the professor in charge at the beginning of the semester during which the work is to be done.

NOTE: Individual courses may be arranged to suit the requirements of graduate students. These special courses are intended to be pursued under the immediate

direction of the professor in charge, the student usually being free from the restriction of the classroom and working either independently or in conjunction with others taking the same course.

ADMINISTRATIVE ENGINEERING

Messrs. CRANDALL, GEBHARD, and THATCHER.

2901. *CONSTRUCTION METHODS.* Required in third year. Credit three hours. Either term. Lectures and recitations three hours a week. A fundamental course designed to acquaint the student with the financial and economic principles underlying construction enterprises, both public and private, and with the agencies —money, men, materials, and machines—utilized in carrying out construction projects, and their correlation and control. Methods and processes of construction with special attention to the equipment required and its adaptability to various kinds of work. Problems and reports on references to periodical literature are required of all students. Texts: *Construction Methods and Machinery,* F. H. Kellogg; *Blasters' Handbook,* DuPont.

2902. *ENGINEERING LAW.* Required in fourth year. Credit three hours. Either term. Lectures and recitations three hours a week. An introductory course in the laws of contract, tort, agency, real property, water rights, form of business organization, sales, and negotiable instruments; special emphasis on contract documents required on construction work; collateral topics such as workmen's compensation, mechanics' liens, bankruptcy, wills, Western water law, and patent law are also included. Text: *Contracts in Engineering,* Tucker.

2903. *ECONOMICS OF ENGINEERING.* Required in fourth year. Credit three hours. Either term. Lectures and recitations three hours a week. Prerequisites, 2901 and 3231. The economic aspects of engineering and the application of principles of management to the work of the engineer; economic selection of materials, equipment and structures; studies for the replacement of existing units; public works economy; the technique of estimating quantities and costs for various types of engineering projects. Texts: *Principles of Engineering Economy,* Grant; *Construction Estimates and Costs,* Pulver.

2904. *PUBLIC ADMINISTRATION.* Required in fifth year. Credit three hours. Either term. Lectures and recitations three hours a week. To acquaint the prospective city engineer, superintendent of public works, city manager, or executive engineer in charge of various government bureaus or departments with the administrative problems he must face in addition to strictly technical engineering duties. Budgets, controlling legislation, civil service regulations, city planning, and public administration practices are included. Text: *Municipal Affairs,* Steele.

2905. *VALUATION ENGINEERING.* Elective for fourth- and fifth-year students. Credit three hours. Lectures and recitations three hours a week. Prerequisite or concurrent courses, Construction Methods, Accounting, Engineering Law. Theory and practice of valuation for purposes of utility rate making, purchase or sale, eminent domain or condemnation cases, securities, bank loans and mortgages, insurance, uniform systems of accounting, and improved management. Text: *Engineering Valuation and Depreciation,* Marston, Winfrey, and Hempstead.

2906. *ADVANCED ENGINEERING LAW.* Elective for fourth- and fifth-year students. Credit three hours. Lectures and recitations three hours a week. Prerequisite, 2902. An extension, by the use of case material, of some of the legal principles covered in 2902, particularly the laws applying to the various phases of construction contracts and employer-employee relationships; additional fields are suretyship, insurance, bailments, and conditional sales. Text: *Law for Engineers and Architects,* Simpson and Dillavou.

2907. *CONSTRUCTION MANAGEMENT.* Elective for fourth- and fifth-year students. Credit three hours. Lectures and recitations three hours a week. Prerequisites, Construction Methods, Economics of Engineering, Accounting. Planning and operation of construction projects by the civil engineer, including coordinated organization of men and machines, scheduling and estimating, purchasing, selection and training of men, operation and maintenance of equipment, cost keeping and reports, pay systems, accident prevention, and other related factors.

2941. *PROJECT. ADMINISTRATIVE ENGINEERING.* Elective. Credit three hours. Either term. The student may select a project involving the design, planning, and construction of any private or public engineering work which is of particular interest to him, with special emphasis upon the legal, financial, and management aspects.

2942. *ADMINISTRATIVE ENGINEERING RESEARCH.* Elective. Credit three hours. Either term. Special problems relating to the economic, legal, and financial aspects of engineering construction projects, management of public works and appraisals.

2943. *ADMINISTRATIVE ENGINEERING SEMINAR.* Elective. One to six hours credit. Open to specially selected seniors or graduate students. Abstraction and discussion of technical papers and publications in the field of administrative engineering.

MECHANICAL ENGINEERING

NUMBERING SYSTEM IN THE SCHOOL OF MECHANICAL ENGINEERING. The first digit (3) of the number designates the School of Mechanical Engineering, the second digit indicates the department in the school, and the third and fourth digits constitute the course numbers within the department. The courses in aeronautical engineering fall under the Graduate School of Aeronautical Engineering. Department numbers are: 0, General; 1, Engineering Drawing; 2, Industrial and Engineering Administration; 3, Machine Design; 4, Materials Processing; 5, Heat-Power Engineering. The following are the numbers of the service courses: Mechanics, 1100 and up; Engineering Materials, 1200 and up. The courses in aeronautical engineering have 7 as the initial digit.

The courses in mechanical engineering are listed under the following headings: Drawing and Descriptive Geometry, Heat-Power Engineering, Industrial and Engineering Administration, Machine Design, Materials Processing.

Required courses in the mechanical engineering curriculum given outside the College of Engineering:

Chemistry 105, 106. General Chemistry (p. 124)
Chemistry 301. Introduction to Organic Chemistry (p. 124)
Chemistry 402. Introduction to Physical Chemistry (p. 125)
Economics 107. Introduction to Economics (p. 125)
English 111, 112. Introductory Course (p. 125)
History 165, 166. Science in Western Civilization (p. 126)
Mathematics 161, 162, 163. Analytic Geometry and Calculus (pp. 126-127)
Physics 115. Mechanics (p. 128)
Physics 116. Wave Motion, Sound, and Heat (p. 128)
Physics 117. Electricity and Magnetism (p. 128)
Physics 118. Physical Electronics and Optics (p. 128)
Psychology 101. Psychology for Engineering Students (p. 130)
Public Speaking 101. (p. 130)

Required courses in mechanics of engineering, strength of materials, and engineering materials are described on pp. 74-79.

GENERAL

3001. *INTRODUCTORY ENGINEERING.* Credit one hour. Two lectures a week. An orientation to the School and to the field of mechanical engineering. A study of the slide rule, problems in engineering, plotting of data, and report writing.

3002. *INTRODUCTORY ENGINEERING.* Credit two hours. Two lectures a week. A continuation of Course 3001 with special emphasis on the responsibilities and opportunities that exist for mechanical engineers in industry. An introduction to modern industrial organization.

3041. *NONRESIDENT LECTURES.* Terms 9 and 10. Required. Total credit one hour for both terms. Both fall and spring terms. One lecture each week.

The course consists of a series of lectures given by lecturers invited from industry and from certain other departments of the University for the purpose of assisting students in their approach to employment and in their transition from college to industrial life.

3051. *A.S.M.E. STUDENT BRANCH.* Credit one hour. Students who have completed at least two terms in the School of Mechanical Engineering are urged to become members of the Cornell Student Branch of the American Society of Mechanical Engineers. The meetings of the Society, however, are open to all. Attendance at any fourteen Student Branch meetings entitles the member to one hour elective credit; however, only one elective hour may be earned in this manner. Application for membership should be made in October of each year at the A.S.M.E. office, West Sibley Basement, or to the Honorary Chairman of the Student Branch, E. B. WATSON, Associate Professor of Mechanical Engineering.

DRAWING AND DESCRIPTIVE GEOMETRY

Messrs. BAIRD, BROWNLOW, CLEARY, HEINZMAN, KENYON, MALGIERI, MORDOFF, and SIEGFRIED.

3111. *DRAWING AND DESCRIPTIVE GEOMETRY.* Credit three hours. Fall term. One hour of freehand drawing and two laboratory periods of mechanical drawing and descriptive geometry a week. Freehand drawing includes studies in freehand sketching, parallel and perspective projection, esthetics in engineering, and applications in creative sketching. Mechanical drawing and descriptive geometry include studies in the prerequisites of mechanical drafting; lettering, delineation and descriptive geometric anatomy.

3112. *BASIC MECHANICAL DRAFTING.* Credit three hours. Spring term. One hour of freehand drawing and two laboratory periods of mechanical drafting a week. Prerequisite, 3111. Continuation of the freehand drawing content of 3111. Mechanical drafting content includes basic layout and detail practice applied to the creation, expression, and interpretation of specifications for mechanical anatomy.

3114. *CREATIVE SKETCHING.* Elective. Credit one hour. Fall term. For students who wish to take only the freehand division of 3111.

3115. *CREATIVE SKETCHING.* Elective. Credit one hour. Spring term. Continuation of 3114 including the freehand division of 3112.

3117. *DRAWING AND DESCRIPTIVE GEOMETRY.* Credit two hours. Fall term. Two laboratory periods a week. Same as 3111 except that freehand drawing is omitted.

3118. *BASIC MECHANICAL DRAFTING.* Credit two hours. Spring term. Two laboratory periods a week. Prerequisite, 3117. Same as 3112 except that freehand drawing is omitted.

3131. *SPECIAL PROBLEMS IN DRAFTING AND INDUSTRIAL DESIGN.* Credit to depend upon hours of actual work. Elective any term for limited number of qualified seniors and graduates. Special problems and investigations in the subject matter, tools, materials, and processes of mechanical drafting and industrial design.

3198, 3199. *PROJECT.* Total credit six hours. These course numbers are assigned to cover work done during the last undergraduate year on a project in the fields of drawing and industrial design. The credit hours given for each course will depend upon the amount and quality of the work done each semester.

INDUSTRIAL AND ENGINEERING ADMINISTRATION

Messrs. ALLEN, BECHHOFER, GAVETT, HALL, HANSELMAN, JOHNSON, KAO, KRICK, LOBERG, McGARRAH, MOORE, PAJKOWSKI, SAMPSON, SAUNDERS, and SCHULTZ.

3231. *PRINCIPLES OF INDUSTRIAL ACCOUNTING AND COST FINDING.* Credit three hours. Two recitations and one computing period a week. A basic course in the principles of industrial accounting including controlling accounts, special journals and ledgers, voucher system, and manufacturing cost systems.

3232. *PERSONNEL MANAGEMENT.* Credit three hours. Three lectures a week. Prerequisite, 3241 or consent of the instructor. This course involves an investigation and evaluation of the techniques used in the handling of personnel functions. The major topics are selection and evaluation of the employee, job analysis, job rating, training, and motivation as well as the organization of the personnel department and its relationship to other departments in an industrial organization.

3233. *REPORT WRITING.* Credit one hour. One recitation a week. Elective for engineering students only. The organization of engineering material into concise written form. This course covers the preparation of engineering reports including organization, description of apparatus and procedures, the graphical presentation and summary of results. It will also include a discussion of business letters of special interest to engineers and written specifications.

3235. *INDUSTRIAL ORGANIZATION AND MANAGEMENT.* Credit three hours. Three lectures a week. The management of an industrial enterprise with special emphasis on problems of internal organization and how this is affected by type of product, methods of manufacture, size of the enterprise, and personnel involved. Types of business enterprises, plant location, centralization and decentralization trends, diversification and specialization, and growth of industry will all be discussed, utilizing actual industrial examples wherever possible.

3236. *ORGANIZATION AND MANAGEMENT OF PRODUCTION.* Credit three hours. Three lectures a week. An introductory course in industrial management covering organizational structure, including types of organization and a discussion of the organization of specific companies; production control, including layout, materials handling, planning, scheduling, routing, dispatching, and inspection; worker productivity, including motion study, time study, job evaluation, and incentive wage plans; and a brief discussion of problems in engineering economy. This course is offered specifically for the School of Industrial and Labor Relations students; engineers may not register for it. Other students may register only by permission of the instructor.

3241. *INDUSTRIAL AND ENGINEERING STATISTICS.* Credit three hours. Two recitations and one computing period a week. Prerequisite, Calculus.

Applications of probability theory and statistics to industrial and engineering problems. Point and confidence interval estimation; the statistical testing of hypotheses. Properties of the binomial, Poisson, and hypergeometric distributions, and applications to sampling inspection problems. Large-sample theory and the normal distribution; small-sample theory and Student's T and the CHI-square distributions. Introduction to correlation theory and curve fitting by the method of least squares.

3242. *STATISTICAL CONTROL AND SAMPLING INSPECTION.* Credit three hours. Two recitations and one computing period a week. Prerequisite, 3241 or permission of the instructor. The concept of statistical control and the Shewhart control chart for attributes and variables. Sampling inspection by attributes and variables; standard sampling plans. Applications, assumptions, underlying theory, and limitations. Problems of organization and administration; application of concept of statistical control to problems in areas other than quality maintenance.

3243. *ADVANCED INDUSTRIAL AND ENGINEERING STATISTICS (I).* Credit three hours. Two recitations and one computing period a week. Prerequisite, 3241 or permission of the instructor. Primarily for graduate students and qualified engineering undergraduates. The application of statistical methods to the efficient design, analysis, and interpretation of engineering or industrial experiments. The rational choice of sample size for various types of tests and the operating characteristic curves of these tests. Curve fitting by the method of least squares; multiple correlation. The planning of multifactor experiments and their analysis by means of the analysis of variance and covariance. Statistical multiple decision procedures.

3244. *ADVANCED INDUSTRIAL AND ENGINEERING STATISTICS (II).* Credit three hours. Two recitations and one computing period a week. Prerequisite, 3243 or permission of the instructor. Intended for graduate students but also open to qualified engineering undergraduates in their fifth year. Experimental designs, randemized blocks, Latin squares, etc. Factorial experiments. Sequential analysis of data. Selected statistical techniques.

3246. *PRINCIPLES OF INDUSTRIAL ACCOUNTING.* Credit two hours. Two periods a week. A basic course in modern industrial accounting including controlling accounts, voucher system, and basic cost classification and principles.

3247. *PRINCIPLES OF COST CONTROL.* Credit three hours. Two recitations and one computing period a week. Prerequisite, 3246 or 3231 or equivalent. Principles of cost accounting for production order and continuous process industrial operations. Cost factors related to decision making, control, and profit; the relation of cost procedures to equipment and personnel organization; the development of budgets and standards.

3250. *INDUSTRIAL ACCOUNTING AND COST CONTROL.* Credit four hours. Three lectures and two computing periods a week are scheduled, but a class will meet only four times a week. Prerequisite, 3235. A basic course in modern industrial accounting theory including detailed study of cost collection systems with emphasis on principles of control. Special journals and ledgers, controlling accounts, voucher system, production order and process type systems; standard costs and budgets. Courses 3231 and 3247 fulfill the requirement for this course.

3253. *CHEMICAL ENGINEERING COST ACCOUNTING.* Credit three hours. Two recitations and one computing period a week. Basic accounting and cost accounting. Emphasis on the cost accounting and cost analysis which applies to the chemical industry. Standards, budgetary control, profit analysis, and statement analysis are discussed briefly to emphasize the necessity of complete cost control.

3254. *STANDARD COSTS AND MANAGEMENT CONTROL.* Credit three hours. One lecture and two computing periods a week. Prerequisites, 3250 or 3247, and 3263 or 3261. A comprehensive study of profit analysis, static budgets, standard costs, flexible budgets, and other cost analyses as applied to production and sales. The establishment of, the organization for, and the control through standards for material, labor, overhead are thoroughly studied. Presentation of the cost information for use by management is emphasized, as are cost aspects of managerial decisions.

3261. *INDUSTRIAL ENGINEERING.* Credit three hours. One lecture and two laboratory periods a week. Prerequisites, 3250, 3404 or equivalent, or consent of the instructor. A course that integrates the several fields of engineering in which a knowledge of machine design, materials, and production tools and processes are utilized to determine correct manufacturing methods and their proper sequence. The laboratory work consists of related problems covering such topics as methods engineering, principles of engineering economy, including economic lot size, materials handling, plant layout, production control, and the production analysis of various manufactured products.

3262. *METHODS ENGINEERING.* Credit three hours. One lecture and two laboratory periods a week. Prerequisite, 3241 or equivalent. Analytical techniques of work study; the design function related to work methods; selection of designs; quantification of work methods; and design of nonrepetitive work methods. Emphasis is placed on human relations problems, physiological aspects of work design, and study of the factors that influence productivity and economy of industrial jobs. Stop watch time study, standard data, and elemental motion standards for incentive rate setting are considered.

3263. *PRODUCTION ENGINEERING.* Credit three hours. One lecture and two laboratory periods a week. Prerequisites, 3250, 3262, 3404, or consent of instructor. The integration of manufacturing engineering functions, including the analysis of the product design from the standpoint of feasible methods of manufacture; the determination of methods of processing and assembly, i.e., machine, tool, jig, and fixture requirements. Such analyses involve the examination of alternatives, justified by application of principles of engineering economy.

3264. *PRODUCTION ENGINEERING.* Credit three hours. One lecture and two laboratory periods a week. Prerequisite, 3263. A continuation of 3263. Problems in plant layout involving process-type and product-type machine arrangements, the design of a balanced-flow production line, the determination of industrial space requirements; basic problems of production scheduling and inventory control. The interdependency of all manufacturing engineering and production control functions is stressed.

3265. *PRODUCTION CONTROL.* Credit three hours. Two recitations and one computing period a week. Prerequisites, 3241, 3250, 3264. Open to graduate students and qualified fifth year engineering students. An intensive study of production management functions, including production forecasting and scheduling, inventory control, production order dispatching, and follow-up. Students are given the opportunity of analyzing quantities of manufacturing data to determine practical measures of effective controls of manufacturing inventories, manpower, and machine utilization. Such analyses involve both empirical and rational techniques, including linear programing.

3266. *ADVANCED METHODS ENGINEERING.* Credit three hours. Two recitations and one laboratory period a week. Prerequisites, 3262 and 3241 or consent of instructor. A critical appraisal of methods engineering practices and principles including ways to maintain time standards; examination of several time study departments; improvement of stop watch time study; derivation of standard

data; theory of predetermined elemental motion time systems; and detailed examination of one such technique; methods-time measurement. Also included are ratio delay studies, psychological factors in machine and job design, and improvement of the variable tasks. Several weeks are spent on projects in areas of special interest to the individual student.

3267. *ADVANCED PRODUCTION ENGINEERING.* Credit two hours. Prerequisite, 3264 or consent of the instructor. Open to graduate students and qualified fifth year students. A study of selected production processes by discussion of possible solutions of typical production problems and situations from a wide variety of industries. Emphasis will be placed on technical and economic problems present as well as on in-process and between-process handling problems. Current trends and concepts of automation will be included.

3270. *INDUSTRIAL MARKETING.* Credit three hours. Three recitations a week. Prerequisites, 3250, 3241. Industrial marketing as related to product planning, policy, and research; sales and market analysis; distribution channels; pricing and terms of sale; sales promotion; management and organization of sales force; sales control. Aspects of related purchasing problems; methods of forecasting sales.

3271. *INDUSTRIAL MARKETING RESEARCH.* Credit three hours. Prerequisite, 3270. Techniques of market research applied to specific problems related to industrial goods.

3290. *SPECIAL INVESTIGATIONS IN INDUSTRIAL AND ENGINEERING ADMINISTRATION.* Credit as arranged. Offered to qualified students individually or in small groups. Involves the study, under direction, of special problems in the field of industrial and engineering administration.

3298, 3299. *PROJECT.* Total credit six hours. These course numbers are assigned to cover work done during the last undergraduate year on a project in the field of industrial and engineering administration. The credit hours given for each course will depend upon the amount and quality of the work done each semester.

MACHINE DESIGN

Messrs. BURR, DuBOIS, GAGNE, KREISLE, MABIE, OCVIRK, PHELAN, SEDGWICK, THOMAS, and WEHE.

3341. *MACHINE DESIGN.* Credit four hours. Required of students in electrical engineering and may be elected by other qualified students not in mechanical engineering. Three recitations and one design-room period a week. Prerequisites, 1153, 1223, 3118, 3402, and 6110. The design of machines and machine members based upon considerations of motion, size, material, strength, durability, and manufacturing processes; selection of cams, linkages, couplings, clutches, brakes, bolts, chains, gears, bearings, shafts, springs, and fasteners. Applications to electrical engineering are emphasized.

3351. *MECHANISM.* Credit three hours. Two recitations and one design-room period a week. Prerequisites, 3112, 1151. A study of displacements, linkages, cams, gears, belts, and trains of mechanism.

3352. *DYNAMICS OF MACHINERY.* Credit three hours. Two recitations and one design-room period a week. Prerequisites, 3351 and 1152. Graphical and analytical studies of velocities and accelerations and of static and inertia forces in mechanism; engine force analysis, flywheels, and balancing.

3353. *DESIGN OF MACHINE MEMBERS.* Credit three hours. One lecture and two design-room periods a week. Prerequisite, 3351, and prerequisite or parallel, 1153 and 1231. Application of mechanics, kinematics, materials, and processes

to the design and selection of machine members such as fastenings, links, springs, translation screws, belts, wire-rope, chains, couplings, clutches, brakes, gears, shafts, and bearings.

3354. *DESIGN OF MACHINES.* Credit three hours. For students in Option A. One lecture and two design-room periods a week. Prerequisites, 3353 and 3404, and prerequisite or parallel, 6113. Application of mechanics, kinematics, materials, and processes to the design of complete machines and the modification of existing machines. Computations and layout drawings as required.

3356. *DESIGN OF MACHINES.* Credit three hours. For students in Option B. One lecture and two design periods a week. Prerequisites, 3353 and 3404, and prerequisite or parallel, 6113. Similar to 3354, but emphasizing the design or modification of production machines and the design of jigs and fixtures.

3361. *ADVANCED MACHINE ANALYSIS.* Credit three hours. Three lectures a week. Prerequisite, 3353. Extended analyses of mechanisms and machinery members such as brakes and bearings. Problems in lubrication, creep, thermal stress, residual stress, surface stress, pressure vessels, and rotating disks, and the graphical determination of shaft deflection.

3366. *ADVANCED KINEMATICS.* Credit three hours. Two lecture-discussion periods and one design period a week. Prerequisite, 3352. Advanced graphical and semi-graphical treatment of velocities and accelerations. Further treatment of Coriolis' acceleration. Advanced analysis and design of cams, gears, and unique linkages. Synthesis of mechanism.

3367. *DESIGN PROBLEMS IN VIBRATIONS AND DYNAMICS.* Credit three hours. Two lectures and one experimental laboratory or computation period a week. Prerequisites, 1155, 3352, 3353. Applications of dynamics and vibration theory to the design of machinery; vibration and shock mounting of machines with single and multi-degrees of freedom, properties of isolators, damping devices, critical speeds of shafts and crankshaft systems, and vibration instruments.

3370. *SPECIAL INVESTIGATIONS IN MACHINE DESIGN.* Credit arranged. Each term. Individual work or work in small groups under guidance in the design and development of a complete machine, in the analysis or experimental investigation of a machine or component of a machine, or studies in a special field of machine design.

3372. *MACHINE DESIGN LABORATORY.* Credit three hours. One lecture and two laboratory periods a week. Prerequisite, 3353. Investigation and evaluation of methods used to obtain design and performance data. Techniques of photoelasticity, strain measurement, photography, vibration and sound measurements, balancing methods, and development techniques are studied as applied to machine design problems.

3373. *CREATIVE DESIGN.* Credit two hours. Two design periods a week. Prerequisite, 3354 or 3356. Layout design emphasizing methods of development of improved designs. Use of short ingenuity problems to stimulate originality

3375. *MACHINERY SURVEY.* Credit three hours. Two lectures and one laboratory period for field trips a week. Prerequisite, 3353. A study of automatic and semiautomatic machinery such as dairy, canning, wire-forming, textile, machine-tool, computing, and printing equipment. Recommended as a Term 8 elective for students considering a project in machine design.

3376. *DESIGN OF OIL HYDRAULIC MACHINERY.* Credit three hours. Prerequisites, 3354 or 3356 and either 2331 or 3520. Three recitations a week. Elective intended for graduate students but open to qualified fifth year students. Methods of generation, application, and control of oil hydraulic power, commer-

cial forms of fixed and variable delivery pumps, fluid motors, valves, control circuits, multispeed and sequence systems, pilot, servo, and tracer mechanisms for use in machine tools and similar applications.

3377. *AUTOMOTIVE ENGINEERING.* Credit three hours. Three lecture-recitations per week. Prerequisite, 3353. Analysis of various designs for the parts of an automotive vehicle, other than the engine, relative to its performance. Stability, weight distribution, traction, steering, driving, braking, riding comfort, power required and available, transmission types, acceleration, and climbing ability are considered. Recommended together with Course 3581 for a study of automotive engineering.

3398, 3399. *PROJECT.* Total credit six hours. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of machine design. Hours of credit given for each course will depend upon the amount and quality of the work done each term.

MATERIALS PROCESSING

Messrs. CARPENTER, CRISSEY, DISPENZA, GEER, HUSON, MORGAN, and YAWGER.

3402. *MACHINE TOOLS.* Credit two hours. One lecture and one laboratory period a week. Demonstrations, discussion, and operation of basic machine tools and their accessories. Demonstrations of the common type of production machine tools and accessories.

3403. *FUNDAMENTALS OF MACHINE TOOLS.* Credit one hour. One laboratory period a week. Demonstrations and operation of the basic machine tools and their accessories. Small tools and their applications.

3404. *PRODUCTION MACHINE TOOLS.* Credit two hours. One lecture and one laboratory period a week. Prerequisites, 3403, 6110. Investigations of some general principles of machine tools, and a study of machine tools and their accessories for volume production, including automatic operation. Jigs and fixtures and advanced tooling techniques, such as those for turret lathes, screw machines, and thread and gear cutting, are discussed and demonstrated.

3405. *GAGE LABORATORY.* Credit one hour. One laboratory period a week. Must be taken with or after 3404. A study of measuring instruments for the control of size, form, and alignment of commercial goods and tools, including gages. Standard techniques of Ordnance, A.S.A., and others are demonstrated and applied in project inspections. Individual experience is acquired in the operation of gaging equipment.

3406. *FUNDAMENTALS OF MATERIALS PROCESSING.* Credit two hours. One lecture and one laboratory period a week. Basic machine tools, their accessories and operation. Small tools and their applications. Workshop measuring methods. Industrial woodworking.

3407. *ADVANCED MATERIALS PROCESSING.* Work and credits as arranged with Mr. GEER.

3411. *CUTTING TOOLS.* Credit three hours. Two lecture periods and one laboratory period a week. Prerequisites, 3403 or equivalent; desirable, 6110 or 1221 or equivalent. The action of the cutting tool. Chip formation and built-up edge. Grain distortion, work hardening and surface stresses. Chip pressure and its measurement. Tool wear and tool life, Woxen's tool-life equation, Ernst-Merchant's force-diagram. Cutting fluids, their performance and application. Machina-

bility of metals. Principal features of cutting tools; angles, nose radii, chip breakers, shear cutting, vibration, and chatter. Current types of single-point and multiple cutting tools. Tool grinding and maintenance.

3412. *MACHINE TOOL OPERATIONS.* Elective for undergraduates and graduate students. Credit three hours. Prerequisite, 3404. One lecture period and two laboratory periods a week. Principal production methods in machine shops. Raw materials and their preparation for production. Work- and tool-holding methods and devices, their relative properties and applications. Sequence of operations, the building up of accuracy. Principal features of conventional machining methods as related to planning, i.e., relative location of work-holding parts and cutting tools. Bench work as applied to manufacturing methods. Tool layout for machine tools; some special methods; thread and gear manufacturing, tool room methods. High precision work. Chip disposal and shop maintenance.

3413. *MACHINE TOOLS.* Credit three hours. One lecture period and two laboratory periods a week. Prerequisite, 3351 or equivalent. Classification of machine tools, dimensional capacities, and current sizes, and some exceptions from established practice. General practice for machine tool speeds and feeds, the arithmetical and the geometrical progression, limitations thereof. Mechanical, hydraulic, and electrical drives for machine tools; performance, efficiency and fields of application. Problems of strength and rigidity in machine tools. Prevention of vibration and chatter. Machine tool slides and ways. Some principal elements of machine tools. Machine tool lubrication, testing, and manufacturing methods. Present trend in development. Obsolescence and modernization, care and maintenance.

3425. *ADVANCED GAGE LABORATORY.* Credit three hours. Prerequisites, 3405, 1221, 1222. One lecture and two laboratory periods a week. An intensive study of gaging practices and standards, as applied to modern industrial manufacture. Application of quality control techniques. Automatic sorting, continuous gaging, and selective assembly inspection. Ultrasonics, electronics, and pneumatic systems and their use. Radiation inspection. Nondimensional inspection.

3498, 3499. *PROJECT.* Total credit six hours. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of materials processing. Hours of credit given for each course will depend upon the amount and quality of the work done each term.

HEAT-POWER ENGINEERING

Messrs. ANDRAE. CLARK, CONTA, DROPKIN, ERDMAN, FAIRCHILD, FAND, GAY, GEBHART, KATZ, MACKEY, MONROE, SHEPHERD, and WATSON.

3501. *ENGINEERING THERMODYNAMICS.* Credit four hours. Two lectures and two recitations a week. Prerequisites, Mathematics 161, 162, 163; Physics 116; Chemistry 105, 106. Fundamental principles of engineering thermodynamics; energy concepts and energy equations; laws of thermodynamics; equilibrium, availability, and reversibility; thermodynamic properties of fluids, including perfect gases, actual gases, vapors, mixtures; nonflow and flow processes, cycles.

3503. *HEAT TRANSFER AND THERMAL MEASUREMENTS.* Credit three hours. Two recitations and one laboratory period a week. Prerequisites, 3501, 3520, 1155. The fundamentals of heat transfer by conduction, convection, and radiation; heat transfer in engineering apparatus. Laboratory instruction in measurement of temperature, thermal conductivity, and film coefficients of heat transfer.

3504. *FUELS AND COMBUSTION.* Credit two hours. Two recitations a week. Prerequisite, 3501. A study of the properties of solid, liquid, and gaseous fuels affecting the design and performance of engineering apparatus. Study of the combustion process including combustion in furnaces and engines.

3510. *ENGINEERING IN FOOD PROCESSING.* Credit three hours. Fall term. Three lecture-recitation periods a week. Prerequisites, elementary physics and chemistry. Primarily for students in the College of Agriculture and School of Nutrition. Not open to engineering students. An introduction to engineering principles of construction and operation of mechanical and electrical equipment used in the preservation and storage of foods.

3521. *STEAM POWER.* Credit two hours. Two recitations a week. Prerequisites, 3501, 3504, 3520, simultaneous registration in 3503. Vapor cycles, combustion equipment, draft apparatus, steam generators, condensers, evaporators, feed-water heaters, pumps, steam engines, steam turbines, complete power plants, industrial uses of steam, heat, and power.

3522. *COMBUSTION ENGINES.* Credit two hours. Two recitations a week. Prerequisites, 3501, 3504, 3520, simultaneous registration in 3503. Study of combustion engines with particular emphasis upon thermodynamics and the combustion process. Application and performance of spark-ignition engines and compression-ignition engines, gas turbines, jet engines, and auxiliaries.

3523. *REFRIGERATION AND AIR CONDITIONING.* Credit two hours. Two recitations a week. Prerequisites, 3501, 3520, 3503. Study of the fundamental theory of refrigeration; analysis of compression, absorption, and steam jet systems; refrigerating equipment and engineering applications. Principles and practice in the conditioning of air, including heating, humidifying, cooling, and dehumidifying.

3524. *HEAT-POWER LABORATORY.* Credit three hours. Two laboratory periods a week. Prerequisites, 3521, 3522, simultaneous registration in 3523. Laboratory study of application, calibration, and accuracy of instruments used in heat-power laboratory. Experimental methods in determining performance of engines, pumps, compressors. Analysis of experimental data; engineering reports.

3530. *ENGINEERING THERMODYNAMICS.* Credit three hours. Three recitations a week. Prerequisites, Mathematics 161, 162, 163; Physics 116; Chemistry 105, 106. Energy concepts and energy equations; thermodynamic properties of gases, vapors, and mixtures; nonflow and flow processes; cycles.

3541. *HEAT-POWER 1.* Credit three hours. Fall term. Two lectures and one two-hour laboratory or computing period a week. Required of students in civil engineering. Prerequisites, Mathematics 161, 162, 163; Physics 116. Energy concepts and energy equations; laws of thermodynamics; properties, processes, and cycles of gases. Internal combustion engines; the compressed air plant.

3542. *HEAT-POWER 2.* Credit two hours. Two lectures a week. Required of students in the School of Civil Engineering. Spring term. Prerequisite, 3541. Properties and processes of vapors; steam engines; steam turbines; the elementary steam power plant. The fundamentals of heat transfer by conduction, convection, and radiation; applications to problems in heat transfer of special interest to students in civil engineering.

3550. *HEAT-POWER RESEARCH.* Credit to depend upon hours of actual work. Recitation and laboratory instruction will be given to a limited number of undergraduates and graduate students interested in work to supplement that given in required courses in the fields of internal combustion engines, power plants, heat transfer, refrigeration, air conditioning, and instruments.

3551. *STEAM TURBINES.* Elective for seniors. Credit two hours. Alternate terms. Two lectures a week. Prerequisite, 3501. Classification of turbines and description of leading features of the various types; mechanical and thermal considerations underlying the action of steam in turbines; calculations involved in turbine design; discussion of building, erecting, and testing; adaptability to special conditions of service; economic results of the use of turbines in engineering practice.

3553. *TEMPERATURE MEASURING INSTRUMENTS.* Elective for seniors and graduates. Credit two hours. One lecture and one laboratory period a week. Prerequisite, 3503 or equivalent. This course covers the theory, construction, calibration, and application of liquid-in-glass thermometers, solid expansion thermometers, pressure-spring thermometers, electrical resistance thermometers, thermoelectric thermometers, optional pyrometers, radiation pyrometers, and other temperature measuring devices.

3554. *DIMENSIONAL ANALYSIS.* Elective for juniors and seniors. Credit two hours. Two lecture-recitation periods a week. Dimensions of physical units. Use of dimensional analysis. Derivation of dimensionless constants. Geometric, dynamic, and kinematic similarity. The principles of similitude and their application to solutions of problems with particular stress on the use of dimensional analysis and the principles of similitude in experimental work.

3555. *GRAPHICAL COMPUTATION AND REPRESENTATION.* Elective to undergraduate students who have completed four terms or to graduate students. Credit two hours. Two recitations a week. Design of slide rules, network charts, and alignment charts; derivation of empirical equations to fit experimental data.

3556. *ADVANCED AIR CONDITIONING.* Credit three hours. Two lectures and one laboratory period a week. Prerequisite, 3523 or equivalent. Selected problems in the study of air conditioning principles and apparatus; panel heating and cooling; the heat pump.

3560. *AIRCRAFT POWER PLANTS.* Credit three hours. Three recitations a week. Prerequisite, senior standing. Operating principles and mechanical and thermal characteristics of reciprocating and rotating types of aircraft power plants. Studies augmented by reading of technical papers and solutions of problems.

3561. *AIRCRAFT ENGINE DESIGN.* Credit three hours. Two laboratory computing periods a week. Prerequisites, 3522, 3353. Engine design principles and pertinent thermodynamic calculations. Design of engine components with regard to functions and loads.

3563. *ADVANCED THERMODYNAMICS.* Intended for graduate students but open to qualified fifth year students. Credit three hours. Three lectures or recitations per week. Prerequisite, 3501, or equivalent. A rigorous and general treatment of the laws of thermodynamics with emphasis on the mathematical development and philosophical interpretations. The pure substance, homogeneous and heterogeneous systems influenced by motion, gravity, and electricity. The significance of the Gibbs and Helmholtz functions in engineering thermodynamics; the Maxwell relations. Quantitative treatment of availability and irreversibility; the criteria of equilibrium.

3564. *THERMODYNAMICS OF FLOW OF COMPRESSIBLE FLUIDS.* Intended for graduate students but open to qualified fifth year students. Credit two hours. Two recitations a week. Prerequisites, 3501 and 3520, or equivalents. The basic differential equation for the flow of gases including area change, friction, mass transfer, and heat transfer; the integrated form of this equation for special cases; Fanno and Rayleigh lines, shock phenomena. Applications to flow in ducts,

diffusers, and nozzles and to design problems on compressors, turbines, ram jets, rockets, and wind tunnels. Demonstration of compressible flow effects by means of the water channel analogy.

3565. *ADVANCED HEAT TRANSFER.* Intended for graduate students but open to qualified fifth year students. Credit two hours. Two recitations a week. Prerequisites, 3501 and 3503, or equivalents. Applications of the "relaxation" method to the solution of problems on heat transfer in the steady state; extended surfaces and two-dimensional heat flow. Numerical analysis of transient and periodic heat flow. Hydraulic and electric analogues.

3566. *COMBUSTION THEORY.* Intended for graduate students but open to qualified fifth year students. Credit three hours. Three recitations a week. Thermodynamics of combustion, use of statistical mechanics in determining properties of high temperature gases, reaction rates, combustion spectroscopy, radiation, aerodynamics of heat addition in compressible flow, laminar and turbulent conduction of flames, detonation.

3570. *AUTOMATIC CONTROL ENGINEERING.* Credit three hours. Two lectures and one laboratory period a week. Prerequisite or parallel courses, 3524 and 3520. A study of the commercially available automatic controllers commonly used in current industrial practice, with special reference to type of construction, installation requirements, and available control patterns. The problems existing in various plants and processes will be discussed, and the influence of the control modes on process behavior will be studied.

3580. *DIESEL ENGINEERING.* Credit three hours. Two lecture-recitation periods, one laboratory or computing period a week. Prerequisites, 3501, 3522. Consideration will be given, both in the classroom and the laboratory, to design and construction of typical diesel engines, fuel injection systems, combustion chamber design and combustion phenomena, engine governors, supercharging, fuels and lubricants for diesel engines, and engine performance. The objective of this course is to emphasize the basic concepts influencing the performance of a diesel engine and its accessories and to provide an opportunity for experimental study of the characteristics of the diesel engine.

3581. *ADVANCED COMBUSTION ENGINES.* Credit three hours. One recitation and two computing periods a week. Prerequisites, 3501 and 3522. Detailed study of operation and design of combustion engines for automotive, marine, and industrial uses; special emphasis on the spark-ignition engine; the matching of engine supply power and propulsion demand power.*

3590. *GAS TURBINE PLANTS.* Elective for graduate students and seniors in mechanical engineering. Credit three hours. Three lectures a week. Prerequisite, 3501. Fundamental study of the cycles and apparatus of the modern gas turbine plant; performance and suitability of this type of power plant for various applications.

3591. *PRINCIPLES OF TURBOMACHINERY.* Credit three hours. Three lectures a week. Prerequisites, 3501 and 3520 (or equivalent). The transfer of energy between a fluid and a rotor; application of thermodynamics and fluid dynamics to rotating machinery; centrifugal and axial flow pumps, compressors, and turbines.

3598, 3599. *PROJECT.* Total credit six hours. Work of the ninth and tenth terms in the form of projects to integrate the training in mechanical engineering when such work is done principally in the field of heat-power engineering.

---

*Recommended together with Course 3377 for a study of automotive engineering.

ELECTRICAL ENGINEERING

COURSES BY GROUPS . . . Within the School of Electrical Engineering, courses are numbered in groups, with each course designated by a four-digit number in which the first digit is 4. The second digit denotes the course group, and the third and fourth digits identify the course within the group.

The descriptions of courses offered in the School of Electrical Engineering follow. Courses in other divisions required of students in electrical engineering are described on pages 122-130.

GENERAL COURSES

Messrs. BRYANT, COTTRELL, ERICKSON, LINKE, MALTI, and STRONG.

4011. *DIMENSIONAL ANALYSIS.* Elective. Credit three hours. Spring term only. Two recitations and one computing period each week. The concept of physical dimensions, fundamental and derived quantities, systems of fundamental quantities and systems of units, numerical relations among systems of units, solution of simple problems by dimensional analysis, determinants and matrices, homogeneous equations, homogeneous functions, linear dependence, Buckingham's π—Theorem, application of Buckingham's π—Theorem to physical problems and to model experiments.

4021. *ENGINEERING REPORTS.* Required. Credit three hours. Fall term only. Three lecture-recitations each week. The objective is to develop the basic principles of exposition, the knowledge of suitable form, and the appreciation of function that will enable students to write and present technical reports that meet professional standards.

4022. *ELECTRICAL ENGINEERING ECONOMY.* Elective. Credit three hours. Spring term only. Two recitations and one computing period each week. Prerequisite, Economics 107. Text: *Principles of Engineering Economy,* Grant. The principles underlying the selection of the most economical method of accomplishing an engineering objective are developed. These include cost of interest, depreciation, return on investment, planning of plant expansion, and the theory and practice of setting rates. Most of the illustrative examples and problems are taken from the electrical engineering field.

4041 and 4042. *NONRESIDENT LECTURES.* Required. Total credit one hour for both terms. Fall and spring terms, respectively. One lecture each week. The course consists of a series of lectures given by lecturers invited from industry and from certain other departments of the University to assist students in their approach to employment and in their transition from college to industrial life. With permission of the professor in charge, attendance at other lectures of suitable subject matter may be substituted for attendance at the lectures of this course.

4091 and 4092. *PROJECT.* Required. Credit three hours for each term. Fall and spring terms, respectively. To develop self-reliance and initiative in working with engineering problems, each student, in his final terms, studies a special problem which is normally closely related to his field of major interest. The choice of a problem is made by the student after consultation with members of the teaching staff. This consultation begins during the term preceding that in which actual work on the project is begun. Project problems may include the following: analysis and study of advanced theory in one of the several branches of engineering or allied fields; analysis and testing of equipment under conditions not considered in regular courses of study; and design, construction, and testing of special apparatus in which the student is particularly interested. Throughout the work the student is expected to conform to good engineering practice in keeping

a complete notebook of day by day tests and investigations. At frequent intervals he is required to submit this notebook to the supervising staff member for discussion, comments, and suggestions. He is expected to submit a well-written technical paper which describes his investigation and summarizes the results.

COURSES IN BASIC ELECTRICAL ENGINEERING

Messrs. ANKRUM, BRYANT, BURCKMYER, COTTRELL, INGALLS, MALTI, NICHOLS, OSBORN, ROSSON, SMITH, STRONG, VRANA, and WILSON.

4110. *BASIC ELECTRICAL ENGINEERING.* Required. Credit three hours. Fall term only. Two recitations and one computing period each week. Prerequisites, Mathematics 162, Physics 116. Text: *Electrical Engineering,* Strong. This is the first of three successive courses presenting the basic elements of electrical engineering which are common to the several branches of study offered later in the curriculum. They present the basic concepts and laws of electricity with concern for their relation to engineering interest. The material in the first course includes energy resources, power efficiency, conductors, and resistance; electromotive force and sources; measurement of electrical quantities; d-c electrical networks; magnetic quantities and circuits; permanent magnets; magnetic forces; induced e.m.f. and inductance.

4111. *ALTERNATING-CURRENT CIRCUITS I.* Required. Credit three hours. Spring term only. Two recitations and one computing period each week. Prerequisites, Mathematics 163, Physics 117, 4110. Text: *Alternating-Current Circuits,* Kerchner and Corcoran. Electromagnetic induction; alternating and power-distribution circuits; self- and mutual-inductance, coupling reactors; electrostatic energy, fields, and forces; capacitance; transient and alternating currents in circuits with resistance and inductance, in circuits with resistance and capacitance, and in series and parallel circuits wth resistance, inductance, and capacitance; and loci.

4112. *ALTERNATING-CURRENT CIRCUITS II.* Required. Credit three hours. Fall term only. One lecture, one recitation, one computing period each week. Prerequisites, Mathematics 607, 4111. Text: *Alternating-Current Circuits,* Kerchner and Corcoran. The study of alternating-current circuits includes series-parallel circuits, and loci; a-c networks, and theorems for solution; equivalent circuits; coupled circuits; air-core and iron-core transformers; transmission lines; power-factor correction; three-phase circuits; balanced three-phase relations; three-phase power; measurement of three-phase power and energy; three-phase transmission; determination of phase sequence; nonsine waves in single-phase and in polyphase circuits; harmonics in three-phase circuits.

4113. *TRANSMISSION LINES AND FILTERS.* Required. Credit three hours. Spring term only. One lecture, one recitation, one computing period each week. Prerequisite, 4112. Text: *Transmission Lines and Networks,* Johnson. A study of the behavior, over a range of frequencies, of circuits with lumped or distributed elements, including filters of the lattice, constant K and derived types, and of transmission lines in the steady state.

4114. *TRANSIENTS IN LINEAR SYSTEMS.* Required. Credit three hours. Fall term only. Two recitations and one computing period a week. Prerequisite, 4112. Transient behavior of circuits with lumped constants; the classical solution of single- and double-energy circuits in the transient state; the ordinary linear differential equation; the Laplace transformation of such an equation; the solution of such an equation by Laplace transforms; systems of ordinary linear differential equations, their Laplace transformation, and their solution.

4115. *TRANSIENTS IN CIRCUITS WITH DISTRIBUTED CONSTANTS.* Elective. Credit four hours. Spring term only. Two lectures and one computing period each week. Prerequisites, 4113 and 4114. Functions of real and complex variables, infinite series, and Laplace and Fourier transforms; the application of these subjects to problems involving transients in transmission lines and networks.

4116. *ELECTRIC-CIRCUIT LABORATORY.* Required. Credit three hours. Fall term only. One lecture and one conference-laboratory period each week. Prerequisites, 4111, Physics 117 and 118. Must be preceded or accompanied by 4112. Text: *Basic Electrical Measurements,* Stout, and mimeographed notes. This course and the two machinery laboratory courses which follow it, 4216 and 4226, require for each topic a preparatory study of references, a laboratory experiment, a written report consisting primarily of solutions of problems based on laboratory and other data, and a group discussion of the reports. The principal topics are basic direct-current circuits, with constant and with varying resistors; application and analysis of circuits in bridges and in other measuring apparatus; thermocouple circuits; temperature measurement and the basic steady-state heat-flow conditions in electrical machines; construction, characteristics, and circuit connections of permanent-magnet moving-coil instruments and of the wattmeter; equipment, procedure, and circuits used in calibrating, checking, and standardizing electrical instruments and secondary standards; the construction, characteristics, and circuit connections of copper-oxide rectifiers and of instruments for measuring alternating voltage and alternating current; characteristics of ideal and of practical resistors, inductors, and capacitors; characteristics of single-phase circuits under approximately sinusoidal conditions of wave form, at power frequencies; characteristics of thermal circuits under elementary transient conditions.

4121. *ELECTRON TUBES AND CIRCUITS.* Required. Credit four hours. Spring term only. Two lecture-recitations, one computing period, and one laboratory each week. Prerequisite, 4112. Text: *Basic Electronics,* Ankrum. This is the first of a group of courses which present and expand the fundamental laws of electron behavior and correlate such behavior with the functioning of simple electronic circuits. The material includes the theory of matter and of electron emission; emitters, conduction in high vacuum and in gas; photoelectric cells; the construction, characteristics, and control of the cathode-ray tube; characteristics of high-vacuum, crystal, and thermionic gas diodes; cold-electrode gas-discharge tubes; rectification; filtering with L-section and π-section filters; studies of the operation and application of thyratrons, pool-type tubes, polyphase rectifiers, and electronic light sources; high-vacuum triode characteristics, parameters, and equivalent circuits.

4122. *ELECTRONIC CIRCUIT ELEMENTS.* Required. Credit four hours. Fall term only. Three lecture-recitations and one laboratory each week. Prerequisite, 4121. Text: *Basic Electronics,* Ankrum. Multigrid vacuum-tube characteristics, parameters, and equivalent circuits; transistor characteristics, parameters and equivalent circuits; application of linear equivalent circuits in devices using high-vacuum tubes and transistors; studies of air-core and iron-core transformers as used in communication systems; studies of small-signal and large-signal amplifiers using high-vacuum tubes and transistors.

4123. *ELECTRONIC CIRCUIT ELEMENTS.* Required. Credit four hours. Spring term only. Three lecture-recitations and one laboratory each week. Prerequisite, 4122. Studies of feedback systems using both positive and negative feedback; amplitude, and angular, modulation and demodulation; multivibrators and blocking oscillators; simple wave-shaping circuits; elements of electronic computers.

4216. *ELECTRICAL MACHINERY LABORATORY.* Required. Credit four hours. Spring term only. One lecture, one recitation, and one laboratory period

each week. Prerequisite, 4116. Text: *Basic Electrical Measurements,* Stout, and mimeographed notes. Direct-current magnetization in general and the magnetic circuits of dynamos; characteristics of direct-current generators and motors with all common methods of excitation; construction, connection, and operating characteristics of typical direct-current motor controllers; measurements of segregated losses, and prediction of efficiency of dynamos by mechanical-drive and by retardation methods; characteristics and typical applications of the Amplidyne. Alternating-current magnetization; a continuation of the study of elementary single-phase a-c circuits; a study of a-c bridge circuits and the detectors commonly used in such circuits.

4221. *ALTERNATING CURRENT MACHINERY.* Required. Credit four hours. Fall term only. One conference and one computing period each week. Prerequisite, 4112. Text: *Alternating Current Machines,* Mueller. The construction, operating characteristics, applications, and control of transformers, synchronous machines, and single-phase and polyphase induction motors. Among the topics are equivalent-circuit diagrams; regulation; losses and efficiency; single-phase and polyphase connection of transformers; parallel operation of synchronous generators; circle diagrams of polyphase induction motors.

4226. *ELECTRICAL MACHINERY LABORATORY.* Required. Credit four hours. Spring term only. One lecture, one recitation, and one laboratory period each week. Prerequisite, 4221. Text: mimeographed notes. A general study of basic principles of alternating-current magnetization and circuit relations involving nonsinusoidal current and voltage, including detailed analysis of balanced and unbalanced polyphase circuits in which harmonics arise in the load or in the generator. Application of these principles in analyzing selected operating characteristics of single-phase constant-potential transformers, instrument transformers, single-phase and three-phase induction motors, and synchronous motors and generators, including parallel operation of the latter.

COURSES IN POWER SYSTEMS AND MACHINERY

Messrs. BRYANT, BURCKMYER, DWU, ERICKSON, LINKE, McILROY, OSBORN, VRANA, and ZIMMERMAN.

4321. *ELECTRICAL MACHINE THEORY.* Elective. Credit three hours. Fall term only. One conference or computing period each week. Prerequisite, 4221. Text: *Electric Machinery,* Fitzgerald and Kingsley. This course extends the analysis of certain subjects of the prerequisite course. Among its topics are analysis of magnetomotive force and of air-gap flux in rotating machines for harmonics in time and in space; effects of such harmonics on induced voltage and on torque; two-reaction analysis of salient-pole synchronous machines; analyses of single-phase induction motors and commutating alternating-current motors.

4326. *POWER LABORATORY.* Elective. Credit three hours. Spring term only. One conference and one laboratory period each week. Prerequisites, 4226 and 4321. Text: mimeographed notes. Salient-pole synchronous-machine principles are examined from the standpoint of the two-reaction theory. The steady-state reactances are measured, and the theory is applied to the analysis of torque-angle relations and the voltage regulation of generators. The measurement and the significance of the transient, and symmetrical component reactances are studied. The course may include symmetrical-component analysis of faults on transmission lines, commutating alternating-current motors, protective relays, or other subjects of special interest to the students enrolled.

4362. *POWER SYSTEM ENGINEERING.* Elective. Credit three hours. Fall term only. Two recitations and one computing period each week. Prerequisites,

4114 and 4221. Text: *Introduction to Electric Power Systems,* Tarboux. The inherent characteristics and performance of complete power systems under both normal and abnormal conditions with emphasis on transmission and distribution portions of power systems but with consideration of the principles of system protection and service reliability.

4363. *POWER SYSTEM STABILITY.* Elective. Credit two hours. Spring term only. Two lecture-recitations each week. Prerequisites, 4362 and 4365. Text: *Power System Stability, Vol. I,* Kimbark. The conditions of stability of synchronous machines and of power systems under both steady-state and transient conditions are investigated.

4364. *POWER SYSTEM PROTECTION.* Elective. Credit three hours. Spring term only. Three lecture-recitations each week. Prerequisites, 4362 and 4365. The principles of the operation of typical relays and of the application of relaying systems; a study of telemetering and supervisory-control equipment.

4365. *POWER SYSTEM ANALYSIS.* Elective. Credit three hours. Fall term only. Prerequisites, 4221 and 4114. The fundamental concept of symmetrical components is developed and is applied to the study of steady-state unbalanced loading of rotating machines, transformers, and power transmission lines. Methods of analyzing the transient behavior of power systems under unbalanced faults are developed and illustrated by problems. Study of the impedances of transmission lines to the several symmetrical components of current.

4371. *HIGH-VOLTAGE PHENOMENA.* Elective. Credit three hours. Spring term only. Prerequisite, 4362. The problems encountered in the normal operation of power systems at very high voltages, of the abnormal conditions imposed by lightning, of the methods employed to assure proper operation of power systems and apparatus under high-voltage conditions, and of the devices available for laboratory testing of equipment under actual or simulated conditions.

COURSES IN INDUSTRIAL ELECTRONICS

Messrs. COTNER and NORTHROP.

4411. *ELECTRONIC CONTROL EQUIPMENT.* Elective. Credit three hours. Fall term only. Two lectures and one lecture-laboratory period each week. Prerequisite, 4123. Text: mimeographed notes. The principles of electronic instrumentation and electronic control systems. The methods of interpreting electronically a stimulus appearing in the form of heat, light, sound, or mechanical movement; and typical electronic circuits through which such electrical effect causes the controlled device to make the desired response. Among these circuits are timing circuits, photoelectric controls, motor controls, welder controls, voltage regulators, and frequency-varying and frequency-discriminating circuits.

4415. *ADVANCED ELECTRONIC CONTROLS.* Elective. Credit three hours. Spring term only. Two recitations and one computing period each week. Prerequisite, 4411. Text: references and mimeographed notes. An intensive study of the theory and the operating characteristics of electronic circuits and equipment used to control and regulate welders, motors, generators, and other machines. These circuits are generalized, compared, and analyzed rigorously. Methods of precise control of time intervals, voltage, current, and frequency are included.

4421. *ELECTRONIC POWER CONVERTERS.* Elective. Credit three hours. Spring term only. Two lectures and one lecture-laboratory period each week. Prerequisite, 4411. Text: mimeographed notes. This course continues the study of the characteristics and the application of some of the electronic power converting devices that were considered in introductory courses, such as power amplifiers, oscil-

lators, single-phase and polyphase rectifiers and inverters, X-ray equipment, and welders. Laboratory work includes inspection and testing of typical equipment, with an analysis of performance.

COURSES IN RADIO AND COMMUNICATION

Messrs. ANKRUM, BOOKER, BURROWS, CREDLE, GORDON, INGALLS, McGAUGHAN, McLEAN, NICHOLS, and WILSON.

4501. *RADIO AND COMMUNICATION SEMINAR.* Elective. One to three hours credit. (Hours credit to be established at the beginning of the term.) Either term. Primarily for graduate students. Reading and discussion of technical papers and publications in the field of radio and communication.

4511. *RADIO AND COMMUNICATION THEORY.* Elective. Credit three hours. Fall term only. Three lecture-recitations each week. Prerequisites, 4113, 4114, and 4123 or their equivalent. A study of the transient and steady state response of circuits; a consideration of noise in communication systems; and elements of information theory. These are considered as basic to the study of communication systems such as television, radar, and computers. Illustrative examples are taken from these fields.

4512. *RADIO AND COMMUNICATION THEORY.* Elective. Credit three hours. Spring term only. Two lectures and one recitation or computing period each week. Prerequisite, 4565 or its equivalent. Communication circuits with distributed constants; production and propagation of electromagnetic radiation; transmission line theory and applications; impedance matching; ultra-high-frequency generation and transmission; electromagnetic theory; propagation phenomena; antenna characteristics and radiation.

4516, 4517. *RADIO AND COMMUNICATION LABORATORY.* Elective. Credit three hours each. Fall and spring terms respectively. Either or both may be taken. One recitation and one laboratory period each week. Prerequisites, 4113 and 4123 or their equivalent. Many different experiments are available among the subjects of electronic circuits, networks, transmission lines, wave guides, and antennas. During the term the student is expected to perform three to five of these, selected to meet his individual needs.

4518. *COMMUNICATION EQUIPMENT SHOP.* Elective. Credit one hour. One lecture-laboratory period each week. Prerequisite, 4123 or its equivalent. During the term some electronic device is constructed and tested. Circuit components are studied in terms of their application in electronic circuits. Experience is gained in the use of hand tools and in circuit layout in accordance with good construction practice.

4526. *DESIGN AND CONSTRUCTION OF VACUUM TUBES I.* Elective. Credit three hours. Normally given in spring term. Two lecture-recitations and one laboratory period each week. Prerequisite, 4122 or its equivalent. The purpose is to acquaint the student with methods by which an electron tube may be designed and its performance predicted and to give a practical insight into the methods and problems of electron tube manufacture. Materials and processing necessary to fabricate simple tubes are discussed. Design considerations involved in heater and cathode design are covered. The theoretical aspects of diode design; triode, tetrode, beam tubes, converter tubes, and other special vacuum-tube types; current manufacturing practices. The laboratory is devoted to the actual construction of several forms of the types considered from the theoretical point of view. The student assembles the elements, completes the necessary glass working and evacuation, and compares the performance with that predicted.

4527. *DESIGN AND CONSTRUCTION OF VACUUM TUBES II.* Elective. Credit three hours. Normally given in fall term. Two lecture-recitations and one laboratory period each week. Prerequisite, 4526. This course continues the work begun in 4526. Subjects include electron beam formation, cathode ray gun design, traveling wave tube construction, ultra-high-frequency tubes utilizing disc seals and other methods of construction; gas-filled tubes and photo-emissive devices; the use of the electrolytic tank for gun design. Simple structures illustrating the various constructions and methods are built in the laboratory by the students. The student carries out the design and fabrication of a tube structure of his own choosing.

4529. *TRANSISTORS.* Elective. Credit three hours. Taught jointly by the Department of Physics and the School of Electrical Engineering. Normally given in fall term. Two lectures and one laboratory period each week. Prerequisites, Physics 214 and 4123 or their equivalent. The motion of electrons and holes in semiconductors; the physical basis of transistor action and semiconductor rectification. Transistors and semiconductor rectifiers are applied as active or passive elements in circuits for use as amplifiers, oscillators, modulators, switches, photoelectric devices and other circuits.

4531. *TELEVISION SYSTEMS.* Elective. Credit three hours. Spring term only. Two lectures and one laboratory or computing period each week. Prerequisite, 4511. The objectives are to demonstrate the application of physical principles in the field of television engineering and to acquaint the student with modern practice in the design and operation of television transmitters and receivers. Basic work in transient analysis, vacuum tube amplifiers, cathode-ray pickup and viewing tubes, cathode-ray beam deflection, pulse shaping, modulation, and antenna characteristics serves as a background for further study of television problems. In addition, such problems as optics, illumination, scanning, synchronization, blanking, and shading are considered. Computations involving the design of various units required for transmission and reception are carried out in the computing periods. Laboratory work consists of experimental work on problems jointly selected by the student and instructor in the field of television and related fields. An inspection of near-by television facilities emphasizes practical aspects.

4541. *APPLIED ACOUSTICS.* Elective. Credit two hours. Normally given in fall term. Two recitations each week. Prerequisite, 4123 or its equivalent. The laws of ideal gases, the thermodynamic properties of air, and the laws of the propagation of compressional waves; the transmission of sound through tubes, horns, and unbounded media. The design of sound sources, microphones, loudspeakers, and wax, lacquer, magnetic, and photographic recorders in keeping with acoustical principles. The phenomena of reflection, absorption, and reverberation and the limitations which these phenomena impose upon architectural design are studied. A brief study of record processing and duplication is included.

4551. *RADIO AIDS TO NAVIGATION.* Elective. Credit two hours. Normally given in spring term. Two recitations each week. Prerequisite, 4123 or its equivalent. Analysis of the principles of directive antennas; discussion of long-wave and medium-wave direction finders and radio beacons; atmospheric effects and limitations on the accuracy of determinations made by such equipment. Medium-frequency pulsed transit-time systems and high-frequency return-signal systems, with application to long-range navigation and precision mapping; airport approach systems and traffic control.

4561. *MICROWAVE COMPONENTS AND TECHNIQUES.* Elective. Credit two hours. Normally given in fall term. Two lecture-recitations each week. Prerequisites, 4565 and 4512 or their equivalent. A study of electrical equipment

particularly applicable to microwave operation, such as magnetrons, klystrons, and other similar generators; measuring devices, transmission systems, wave guides, coaxial lines, and cavity resonators. It is recommended that 4516 or 4517 be taken for laboratory work associated with this course.

4563. *PULSE TECHNIQUE IN COMMUNICATION AND RADAR.* Elective. Credit three hours. Fall term only. Three recitations each week. Prerequisites, 4114 and 4123, or their equivalent. The transmission of information and the detection of objects by means of discrete pulses rather than by continuous waves. Among the topics are analysis of signal functions, especially of pulses and related signals; noise analysis; basic principles of pulse generation, modulation, transmission, and reception; fundamental circuits of pulse techniques; application to radar; pulse communication systems, known as pulse-amplitude, pulse-time, pulse-position, and pulse-code modulating systems.

4564. *TRANSMISSION OF INFORMATION.* Elective. Credit three hours. Spring term only. Three recitations each week. Prerequisite, 4563 or its equivalent. The general aspects of a transmission system (the source of information, the transmitter, the channel, the receiver, and the final destination of the message). The definition of information and a quantitative measure of information; the statistical properties of the source, its entropy, and the rate at which information is produced by the source. The transformation of primary signal functions into secondary signal functions at the transmitter, the capacty of the channel to transmit the secondary signal function in the presence of channel noise, and the possibilities of recovering the primary signal function at the receiver. The over-all performance of transmission is discussed as to fidelity and the effective rate of transmission. These principles are applied to pulse-code modulation as an example of modern transmission of information.

4565. *ELECTROMAGNETIC THEORY.* Elective. Credit three hours. Fall term only. Prerequisite, 4113 or its equivalent. Three lecture-recitations each week. The foundations of electromagnetic theory required for study of radio wave communication. A critical examination of the significance of the electromagnetic vectors and their relations; a discussion of the principles involved in guided and unguided propagation.

4566. *RADIO WAVES I.* Elective. Credit three hours. Spring term only. Prerequisite, 4565 or its equivalent. Three lecture-recitations each week. This course, together with 4567, describes how propagation of radio waves is influenced by the earth, the lower atmosphere, and the ionosphere. Topics are the Sommerfeld theory of propagation over a flat earth, diffraction round a spherical earth, superrefractive propagation in atmospheric ducts, propagation in an ionized atmosphere, reflection from the ionosphere at both normal and oblique incidence, and the influence of the earth's magnetic field upon ionospheric propagation.

4567. *RADIO WAVES II.* Elective. Credit three hours. Fall term only. Prerequisite, 4566. Three lecture-recitations each week. A continuation of 4566.

4568. *ANTENNAS.* Elective. Credit three hours. Spring term only. Prerequisite, 4565 or its equivalent. Three lecture-recitations each week. The theory of transmission and reception by dipoles, slots, broadside antennas, end-fire antennas, horns, and paraboloids; the detailed electromagnetic field involved in simple antennas.

4571. *ADVANCED COMMUNICATION NETWORKS.* Elective. Credit three hours. Normally given in spring term. Three recitations each week. Prerequisite, 4113 or its equivalent. Among the topics considered are mesh and nodal analysis, the complex frequency plane, conditions for physical realizability, representation of driving-point and transfer impedance functions by physical networks, topics in the design of impedance functions.

COURSES IN ILLUMINATION

Messrs. COTTRELL and STRONG.

4611. *INTRODUCTORY ILLUMINATION.* Elective. Credit three hours. Fall term only. Two recitations and one laboratory-computing period each week. Prerequisite, Physics 118. Text: *Scientific Basis of Illuminating Engineering,* Moon. The course is to acquaint the student with the general nature of illuminating engineering. Introductory study in several basic aspects provides an appreciation of the problems commonly encountered and the methods of solution. Topics are sources of light; visual perception and illusion; light control, both spectral and directional; the units and the measurement of the strength of light sources and of the intensity of illumination; general illumination design; perception, production, and mixing of colors; shadows, desirable and undesirable; architectural objectives.

4612. *ILLUMINATING ENGINEERING.* Elective. Credit three hours. Spring term only. Two recitations and one laboratory-computing period each week. Prerequisite, 4611, Text: *Scientific Basis of Illuminating Engineering,* Moon. This course extends the study of some of the topics introduced in the prerequisite. Study of current literature supplements the text. Computation of light-flux distribution and study of difficult lighting problems; emphasis on industrial lighting problems more specialized than the problems of general lighting.

4615. *ILLUMINATION SEMINAR.* Elective. Credit two hours. Fall term only, on sufficient demand. One two-hour period each week. Must be accompanied by 4611. Reports on selected topics of current interest in illuminating engineering.

COURSES IN SERVOMECHANISMS

Messrs. MESERVE and ROSSON.

4711. *SERVOMECHANISM I.* Elective. Credit three hours. Fall term only. Two lecture-recitations; one laboratory or computing period each week. Prerequisites, 4123, 4216, 4221 and 4226. Text: *Servomechanism Analysis,* Thaler and Brown. The principles of servomechanisms and regulating systems with emphasis on the analysis of servomechanism performance from equations and transfer-function plots. Review of the Laplace transformation, error detecting devices, hydraulic devices, equations and physical systems, transient analysis, transfer functions and their graphical representation; factors affecting error, damping, and speed of response; criteria for stability.

4712. *SERVOMECHANISM II.* Elective. Credit three hours. Spring term only. Two lecture-recitations and one laboratory or computing period each week. Prerequisite, 4711. Text: *Servomechanism Analysis,* Thaler and Brown. Feedback control systems are synthesized, and their performance is predicted by the use of stability criteria. Laboratory tests for the comparison of observed and predicted performance of servo systems. Topics include introduction to design, gain adjustment, series and parallel compensation, relay servomechanisms and the Root-locus method.

4713. *SERVOMECHANISMS SEMINAR.* Primarily for graduate students. Elective. Credit two hours. Fall term only. One two-hour period each week. Prerequisites, 4711, 4712. Reports on selected topics such as relay servomechanisms, nonlinear effects on servomechanism analysis and performance, sampled data systems, power requirements, analog computers for servo analysis and synthesis, and statistical analysis of servomechanisms.

4810. *INTRODUCTION TO ELECTRONIC COMPUTERS.* Elective. Credit three hours. Spring term only. Two lecture recitations and one laboratory period

each week. Prerequisites, 4114 and 4123 or the equivalent. An introduction to the field of electronic computing devices, their philosophy, operation, design, principles, and use. Analogue computers are treated in detail with a brief discussion of digital and other computers.

ELECTRICAL COURSES REQUIRED IN OTHER ENGINEERING CURRICULA

Messrs. BRYANT, COTTRELL, ERICKSON, LINKE, MESERVE, and STRONG.

4931. *ELECTRICAL ENGINEERING.* Required of students in chemical engineering, civil engineering, and mechanical engineering. Credit three hours. Fall and spring terms. One lecture, one recitation, and one computing period each week. Prerequisites, Mathematics 163, and Mechanics 1132 or 1152. An elementary study of direct-current electric circuits; the concepts of resistance, inductance, and capacitance; magnetic circuits; single-phase and three-phase alternating-current circuits; and instruments and techniques appropriate for making measurements in all such circuits.

4932. *ELECTRICAL ENGINEERING.* Required of students in chemical engineering, civil engineering, and mechanical engineering. Credit three hours. Fall and spring terms. One lecture, one recitation, and one laboratory or computing period each week. Prerequisite, 4931. The course is to develop a general understanding of d-c generators and motors, motor starters and controllers, transformers, induction motors, synchronous machines, a-c single-phase motors, and d-c and a-c selsyn units. All machines are considered as to construction, theory of operation, and operating characteristics.

4933. *ELECTRICAL ENGINEERING.* Required of students in chemical engineering and mechanical engineeering. Credit three hours. Fall and spring terms. One lecture, one recitation, and one laboratory or computing period each week. Prerequisite, 4932. The aim is to develop an understanding of the possibilities of electronic control. Included is a study of the characteristics and applications of the various commonly used electron tubes and a study of such general topics as rectifiers, amplifiers, and oscillators. Quantitative analysis is avoided except when it might aid in understanding the function of a circuit.

4934. *PRINCIPLES OF AUTOMATIC CONTROL.* Term 10. Required of mechanical engineering students in Option A. Credit three hours. Spring term only. One lecture, one recitation, and one laboratory or computing period each week. Prerequisite, 4933. The mathematics of automatic control as exemplified in servo devices, with analysis of electrical, mechanical, and hydraulic applications. Problems of electrical instrumentation in automatically controlled operations and processes.

4983. *BASIC ELECTRICAL ENGINEERING.* Required of students in engineering physics. Credit four hours. Spring term only. One lecture, two recitations, one computing period each week. Prerequisites, Mathematics 163, Physics 117. The engineering approach in the study of direct-current and alternating-current circuits, magnetic circuits including permanent magnetic material, and the basic elements associated with these general topics.

4991. *ELECTRONIC CIRCUITS.* Elective. Credit three hours. Three lecture-recitations each week. Prerequisites, 4933 and Mathematics 201, or equivalent. Texts: Selected references and mimeographed notes. This course is offered to graduate students who are majoring in an engineering field other than electrical. It is designed to supplement the basic electronic work normally included in an

undergraduate program. Circuits including diodes, triodes, pentodes, and other high-vacuum multi-element tubes are considered. Among the topics are amplifiers, degenerative and regenerative feedback, modulation and demodulation, and pulse shaping.

CHEMICAL AND METALLURGICAL ENGINEERING

Required courses in the chemical and metallurgical engineering curricula given outside the school:

Chemistry 111, 112. Introductory Inorganic Chemistry (p. 124)
115, 116. Introductory Chemistry Laboratory (p. 124)
307, 308. Introductory Organic Chemistry (p. 124)
311. Introductory Organic Laboratory (p. 124)
312. Intermediate Organic Laboratory (p. 124)
403, 404. Introductory Physical Chemistry (p. 125)
411, 412. Introductory Physical Laboratory (p. 125)
English 111, 112. Introductory Course (p. 125)
Electrical Engineering 4931, 4932, 4933 (p. 114)
Geology 712, Metallurgical Raw Materials (p. 126)
History 165, 166. Science in Western Civilization (p. 126)
Mathematics 161, 162, 163. Analytical Geometry and Calculus (pp. 126-127)
Mechanics and Materials of Engineering (p. 74)
Mechanical Engineering Courses (p. 93)
Physics 115. Mechanics (p. 128)
116. Wave Motion, Sound, and Heat (p. 128)
117. Electricity and Magnetism (p. 128)
118. Physical Electronics and Optics (p. 128)
Public Speaking 101 (p. 130)

CHEMICAL ENGINEERING

5101, 5102. *INTRODUCTORY CHEMICAL ENGINEERING.* Credit two hours a term. Consecutive terms. Lectures. Prerequisites, Chemistry 111 and 112. An introduction to the processes and calculations of chemical engineering. Mr. WINDING.

5103. *CHEMICAL ENGINEERING THERMODYNAMICS.* Fall term. Credit three hours. Prerequisites, Chemistry 403 and 404. Lectures. The development of the fundamental principles of thermodynamics, with special attention to their application to chemical engineering processes. Mr. VON BERG.

5104. *CHEMICAL ENGINEERING THERMODYNAMICS.* Spring term. Credit three hours a term. Prerequisite, 5103. Continuation of 5103. Mr. VON BERG.

5106. *CHEMICAL ENGINEERING KINETICS.* Credit two hours. Spring term. Two lectures a week. Prerequisite, 5104. The kinetics of chemical engineering reactions and processes. Mr. VON BERG.

5203, 5204. *CHEMICAL ENGINEERING TECHNOLOGY.* Credit two hours a term. Consecutive terms. Lectures. A discussion of the important chemical engineering processes and industries. The first term is devoted to the consideration of inorganic chemical technology; in the second term, the discussion deals with the organic chemical engineering industries. Mr. WIEGANDT.

5303, 5404. *UNIT OPERATIONS OF CHEMICAL ENGINEERING.* Credit three hours a term. Consecutive terms. Lectures. Prerequisite or parallel courses, Chemistry 403 and Engineeering 5203 and 5204. A critical discussion of the unit operations of chemical engineering. Mr. RHODES.

5353, 5354. *UNIT OPERATIONS LABORATORY.* Credit three hours a term. Two terms. Prerequisites, Engineering 5303 and 5304. Messrs. RHODES, SMITH, and assistants.

5503, 5504. *CHEMICAL ENGINEERING COMPUTATIONS.* Credit two hours a term. Consecutive terms. Conferences and lectures. Prerequisite or parallel course, 5304. Problems in fluid flow and heat transfer, distillation, evaporation, drying, humidification and air conditioning, and filtration. Mr. WINDING.

5505. *ADVANCED PROBLEMS IN HEAT TRANSFER.* Credit two hours. Spring term. Conferences and lectures. Prerequisite, 5503 or equivalent. Advanced topics in heat transfer. Heat transfer to fluids in streamline flow; heat transfer under unsteady-state conditions; heat transmission in mixed-flow heat exchanges, etc. Primarily for graduate students. Mr. SMITH.

5506. *ADVANCED PROBLEMS IN DIFFUSIONAL OPERATIONS.* Credit three hours. Fall term. Primarily for graduate students. Prerequisites, 5503, 5504, or equivalent. Conferences and lectures. Advanced topics in distillation, gas absorption, liquid-liquid extraction, and drying. Mr. WINDING.

5603, 5604. *CHEMICAL ENGINEERING EQUIPMENT.* Credit two hours a term. Two lectures a week. Prerequisite, 5304. Details of design and construction of chemical engineering equipment; piping, design of pressure vessels, detailed design of process equipment. Mr. SMITH.

5605, 5606. *CHEMICAL PLANT DESIGN.* Credit two hours a term. Two terms. Individual problems in the design of complete chemical plants, with estimation of costs of construction and operation. Staff.

5701. *PLANT INSPECTIONS.* Credit one hour. Spring term. A series of supervised inspection trips to manufacturing plants representing various chemical engineering industries. Each student is required to submit a critical and comprehensive report. Messrs. RHODES and WINDING.

5711. *LIBRARY USE AND PATENTS.* Credit one hour. Fall term. The effective use of technical literature; literature searches; abstracts and bibliographies; patent law. Messrs. RHODES and MASON.

5741. *PETROLEUM REFINING.* Credit three hours. Alternate terms. Three lectures a week. Prerequisite, 5304. Processes employed in petroleum refining. Mr. WIEGANDT.

5742. *TECHNOLOGY OF HIGH POLYMERS.* Credit three hours. Alternate terms. Prerequisite, Chemistry 404. Polymerization reactions, manufacture and properties of synthetic resins, fibers, plastics, and rubbers. Mr. WINDING.

5745. *CONTROL OF ENGINEERING PROCESSES.* Credit three hours. Fall term. Lectures. Hours to be arranged. Prerequisites, 5304 and 5354 or 6204 and 6254. The methods used for operation control and quality control in chemical engineering processes. Mr. RHODES.

5746. *CHEMICAL ENGINEERING ECONOMICS.* Credit three hours. Fall term. Three lectures each week. Prerequisite, 5304 or special permission. The economic aspects of research, development, manufacturing, and sales in the chemical industries. Mr. HEDRICK.

5851. *CHEMICAL MICROSCOPY.* Credit three hours. Either term. One lecture and two laboratory periods each week. Prerequisite or parallel courses,

Chemistry 403, 404 or 407, 408 and Physics 117, 118 or special permission. The use of microscopes and their accessories in chemical and technical investigations. Micrometry; quantitative estimations; microscopical charactersistics and physical chemistry of crystals; lens systems and photomicrography; study of industrial materials. Mr. MASON and assistants.

5853. *MICROSCOPICAL QUALITATIVE ANALYSIS (INORGANIC).* Credit two or more hours. Either term. Laboratory periods to be arranged. Prerequisite, 5851. Laboratory practice in the analysis of inorganic substances containing the more common elements. Mr. MASON.

5859. *ADVANCED CHEMICAL MICROSCOPY.* Credit one or more hours. Either term. Prerequisite, 5851 and special permission. Laboratory practice in special methods and special applications of chemical microscopy. Mr. MASON and assistants.

5953, 5954. *SENIOR PROJECT.* Credit three hours a term; additional credit by special permission. Consecutive terms. Prerequisite, 5304. Research on an original problem in chemical engineering. Staff.

5955. *SPECIAL PROJECTS IN CHEMICAL ENGINEERING.* Credit variable. Either term. Prerequisite, 5954. Research or studies of special problems in chemical engineering. Staff.

METALLURGICAL ENGINEERING

6110. *CASTING, WORKING, AND WELDING OF METALS.* Credit two hours. Either term. One lecture and one laboratory period each week. An elementary course covering the important industrial processes used in the casting, hot working, cold forming, and welding of metals. The utilization of metallurgical processes in other branches of engineering is stressed. Messrs. BURTON, HARPER, HODGES, and JOYCE.

6111. *INTRODUCTORY METALLURGY.* For students in metallurgical engineering. Credit two hours. Fall term. One lecture and one laboratory period each week. An introduction to the principles of metallurgy. Covers a number of metallurgical processes and includes laboratory work in casting, metal working, welding, and heat treatment. Messrs. BURTON, HARPER, HODGES and JOYCE.

6113. *METALLURGY OF CASTING, WORKING, AND WELDING.* Credit three hours. Fall term. Two lectures and one laboratory period each week. Prerequisites 1231 and 6110. An advanced course for students in mechanical engineering covering the application of metallurgical principles to foundry, metal working, and welding problems. Mr. BURTON, and assistants.

6114. *METALLURGY OF CASTING, WORKING, AND WELDING.* Credit three hours. Spring term. Three lectures and one laboratory period each week. Prerequisites, 6111 and 6811. For students in metallurgical engineering. A critical study of selected processes in the fields of casting, metal forming and working, welding, and power metallurgy. Emphasis is placed on the metallurgical principles involved, the metallurgical factors governing control of the processes, and the influence of the processing methods on the final products. Mr. BURTON.

6120, 6121. *ADVANCED FOUNDRY ENGINEERING.* Credit three hours a term. Consecutive terms. Lectures, recitations, and special laboratory studies. Prerequisite 6113 or 6114. Critical study of foundry technology and the metallurgical features of cast metals. Laboratory investigation of special foundry processes and procedures. Mr. BURTON.

6203, 6204. *SMELTING AND REFINING.* Credit three hours a term. Consecutive terms. Lectures. Prerequisites, Chemistry 404 and Engineering 1256, 6501. A study of methods of extraction of metals and alloys of commerce. Consideration is given to principles of ore beneficiation and to fundamentals of metallurgical practice, including details of production and utilization of heat. The commercial processes for the reduction and refining of individual metals together with limitations and problems arising from these processes are analyzed. A detailed consideration of the furnace operations in the manufacture of iron and steel illustrates the application of physicochemical principles to the industrial production of useful alloys. Mr. GREGG.

6221. *ADVANCED PROCESS METALLURGY.* Credit two hours. Fall term. Lectures and conferences. Prerequisites, 6203 and 6204. An advanced course covering production of metals and alloys. Emphasis on the application of thermodynamics to the study of the extraction and refining of metals. Mr. GREGG.

6253, 6254. *UNIT PROCESSES IN METALLURGY.* Credit three hours a term. Consecutive terms. One lecture and one laboratory period each week, with reports. Parallel courses, 6203, 6204. Experimental study of important processes in metallurgy, including ore dressing, temperature measurements, generation and control of furnace atmospheres, furnace design and performance, smelting and refining operations and electrodeposition. Reports based on the experimental data, discussing the principles involved in the operations, are an important part of the course. Mr. GREGG.

6311, 6312. *PHYSICAL METALLURGY.* Credit two hours per term. Consecutive terms. Prerequisite, 6811. Detailed discussion of plastic deformation, recrystalization and grain growth, diffusion in alloys, precipitation from solid solution, and transformation mechanisms in heat treatment. Messrs. MASON and BURTON.

6351. *PHYSICAL METALLURGY LABORATORY.* Credit three hours. Fall term. Laboratory periods and conferences. Parallel course 6311. Theory and metallurgical application of X-ray diffraction, and experiments to illustrate the important phenomena of physical metallurgy and techniques for their investigation. Determination of lattice types, parameter measurements, pole figures, and single crystal orientation by X-ray methods. Messrs. BURTON and MASON.

6501. *METALLURGICAL CALCULATIONS.* Credit two hours. Fall term. Lectures and recitations. Prerequisite, 1255. An introductory course in the application of the principles of chemistry and physics to metallurgical problems, including combustion, heat balances, gas reactions, and furnace changes. Mr. GREGG.

6602. *METALLURGICAL DESIGN.* Credit three hours. Spring term. Lectures and conferences. Prerequisite, 6312. Metallurgical and mechanical factors governing the selection of metals for various services. Analysis of service requirements, and the selection and fabrication of metals to fulfill such requirements; analysis of service failures of metals and remedies for such failures; and study of the merits and limitations of materials applications in existing products and equipment. Mr. BURTON.

6701. *PLANT INSPECTION.* Credit one hour. Spring term. A series of supervised inspection trips to manufacturing plants representing various metallurgical engineering industries. Each student is required to submit a comprehensive report. Staff.

6811. *INTRODUCTORY METALLOGRAPHY.* Credit three hours. Spring term. One lecture and two laboratory periods each week. Prerequisites, 1255 or 1222. Microstructures of alloys, as related to composition, thermal history, and

physical properties. Preparation of specimens; principles and use of metallographic microscopes. Messrs. MASON and BURTON.

6953, 6954. *SENIOR PROJECT.* Credit two hours each term. Two terms. Prerequisite, 6254. Research on an original problem in metallurgical engineering. Messrs. MASON, GREGG, and BURTON.

AERONAUTICAL ENGINEERING

UNDERGRADUATE COURSES

7001. *INTRODUCTION TO AERONAUTICAL ENGINEERING.* Credit three hours. Given as required. Prerequisite, engineering mechanics. An introductory course for students in all branches of engineering. Emphasis on airplane mechanics; aerodynamic forces, airplane performance, airplane stability and control.

GRADUATE COURSES

7101. *MECHANICS OF AIRPLANES.* Credit three hours. Fall term. Prerequisite, engineering mechanics. Physics of the atmosphere, properties of gases and fluids; similarity laws. Inviscid incompressible flow; momentum methods; vortices; introduction to airfoil and wing theory. Basic properties of compressible flow at subsonic, transonic, and supersonic speeds. Introduction to the methods of viscous flow theory; viscous drag; experimental methods. Estimation of airplane performance. Static longitudinal stability and control, stick-fixed and stick-free, power effects. Mr. ROTT.

7102. *MECHANICS OF AIRPLANES.* Credit three hours. Spring term. Prerequisite, 7101. Dynamics of longitudinal motion; phugoid motion; longitudinal stability, stick-fixed and stick-free; stability criteria. Lateral dynamics; discussion of derivatives; lateral stability, controls fixed and free; discussion of modes. Autorotation and spin. Response to controls; operational methods; automatic stabilization and autopilot. Mr. ROTT.

7203. *AERODYNAMICS OF POWER PLANTS.* Credit three hours. Fall term. Prerequisite, engineering thermodynamics. Cycle thermodynamics; the gas-turbine process. Thermodynamics of flow. Cycle and analysis of turbojets, ramjet, turboprop, ducted fan, afterburner, etc. Heat transfer by force convection at high speeds; gas properties, Reynolds analogy; radiator and heat-exchanger design. Elements of the jet-propulsion engine; combustion chamber; aerodynamic design of compressors and turbines. Rockets. Mr. ROTT.

7204. *GASDYNAMICS.* Credit four hours. Spring term. Prerequisite, permission of the instructor. One-dimensional steady flow of a perfect gas with heat addition, etc., wave-propagation phenomena, method of characteristics for 2-dimensional and axi-symmetric supersonic steady flow and unsteady channel flow. Experimental methods. Mr. KANTROWITZ.

7206. *SPECIAL TOPICS IN PHYSICAL GASDYNAMICS.* Credit two hours. Given as required. Prerequisites, 8121, 8122, or equivalents, and 7204. A study of various gasdynamical problems in which the molecular kinetics plays an important role. Specific topics to be chosen by consultation. Mr. KANTROWITZ.

7301. *THEORETICAL AERODYNAMICS I.* Credit three hours. Six hours a week during the first half of the fall term. Prerequisites, differential equations, intermediate mechanics or introduction to theoretical physics. Introduction to theoretical hydrodynamics. Ideal fluids. The boundary-value problems of steady

and nonsteady two- and three-dimensional potential flows with special attention to flows produced by the motion of solid bodies. Vector methods and complex variable are used extensively. Mr. SEARS.

7302. *THEORETICAL AERODYNAMICS II.* Credit three hours. Spring term. Prerequisites, 7301, 7303. Wing theory: thin-airfoil theory, two-dimensional airfoil theory. Prandtl wing theory, lifting surfaces, general multiple theory, nonstationary wing theory. Correction for compressibility (linearized theory). Wing theory for supersonic speeds; source and sink methods and extensions, conical-flow methods, nonstationary cases. Mr. SEARS.

7303. *THEORETICAL AERODYNAMICS III.* Credit three hours. Six hours a week during the second half of the fall term. Prerequisites, 7204, 7301. The aerodynamics of compressible fluids: equations of motion, small-perturbation theory (subsonics and supersonic); Janzen-Rayleigh theory, the hodograph methods, the limiting line, the method of characteristics, Prandtl-Meyer flow, hypersonic flow. Messrs. KUO and SEARS.

7304. *THEORETICAL AERODYNAMICS IV.* Credit three hours. Spring term. Prerequisite, 7301. The aerodynamics of viscous fluids: the boundary layer, heat transfer, fundamentals of boundary-layer stability. Turbulence, the fundamentals of isotropic turbulence. Experimental methods. Mr. KUO.

7305. *AERODYNAMICS OF COMPRESSIBLE VISCOUS FLUIDS.* Credit two hours. Fall term. Prerequisite, 7304. The theory of boundary layers and heat transfer in compressible fluids. Phenomena of interaction between shock waves and boundary layer. Experimental methods. Mr. KUO.

7401. *AIRPLANE STRUCTURES.* Credit three hours. Fall term. Prerequisite, Strength of Materials. Stress analysis of typical airplane structures: trusses, frames, wing structures. Torsion. Shear. Use of stress function. Plastic failure. Failure by buckling: stability of thin-walled structures, theory of shells. Mr. RIPARBELLI.

7402. *AIRPLANE STRUCTURES.* Credit three hours. Spring term. Prerequisite, strength of materials. Fatigue: stress concentration, mechanical vibrations. Impact stresses: response of transient loading conditions. Influence of elastic deformations on aerodynamic loads: static divergence. Wing flutter. Mr. RIPARBELLI.

7403. *AIRPLANE DESIGN.* Credit one hour. Fall term. Orientation: the airplane and its components; the philosophy of airplane design; aircraft materials and processes. Messrs. RIPARBELLI and SEARS.

7404. *AIRPLANE DESIGN.* Credit one hour. Spring term. Prerequisite, 7403. Orientation (continued). Messrs. RIPARBELLI and SEARS.

7405. *AERO-ELASTIC PROBLEMS.* Credit one hour. Spring term. Prerequisites, 7101 and 7102. Wing divergence and aileron reversal for straight and swept wings. Gust loads on the elastic airplane. Flutter calculations. Discussion of flutter modes involving control-surface vibration. Mr. ROTT.

7406. *SPECIAL METHODS OF STRUCTURAL ANALYSIS.* Credit two hours. Given as required. Prerequisites, 7401 and 7402. Problems in impact stress distribution. Aero-elastic problems. Wing flutter with two and three degrees of freedom. Mr. RIPARBELLI.

7407. *DYNAMICS OF STRUCTURES.* Credit three hours. Given as required. Prerequisite, Strength of Materials. Vibrations, impact, transverse impact. Properties of materials as functions of rate of load. Fundamentals of plasticity. Dynamic failure. Some laboratory work will be required. Mr. RIPARBELLI.

7801. *RESEARCH IN AERONAUTICAL ENGINEERING.* (Credit to be arranged.) Prerequisites, admission to the Graduate School of Aeronautical Engineering and approval of the Director. Independent research in a field of aeronautical science. Such research must be under the guidance of a member of the staff and must be of a scientific character.

7901. *AERONAUTICAL ENGINEERING COLLOQUIUM.* Credit one hour. Prerequisite, admission to the Graduate School of Aeronautical Engineering. Lectures by staff members, graduate students, personnel of Cornell Aeronautical Laboratory, and visiting scientists on topics of interest in aeronautical science, especially in connection with new research.

7902. *ADVANCED SEMINAR IN AERONAUTICS.* Credit two hours. Prerequisite, approval of the Director. Same as 7901 but devoted to topics of advanced scientific interest.

ENGINEERING PHYSICS

8010. *APPLIED NUCLEAR AND REACTOR PHYSICS.* Credit three hours. Spring term. Three recitations a week. Prerequisites, sophomore physics and mathematics. Atomic and nuclear structure, binding energy, isotopes, characteristics of high energy machines, nuclear reactions, cross sections, artificial transmutations and uses thereof, properties of neutrons, interactions of neutrons with matter, nuclear fission and nuclear reactors, elementary reactory theory, types of reactors, problems in reactor design, instruments for detection and measurement, protection for personnel, radioactive tracer techniques and application to engineering problems.

8051 and 8052. *PROJECT.* Terms 9 and 10. Credit three hours each term. Fall and spring terms, respectively. Informal study under direction of a member of the University staff. The objective is to develop self-reliance and initiative, as well as to gain experience with methods of attack and with over-all planning, in the carrying out of a special problem related to the student's field of interest. The choice of a problem is to be made by the student in consultation with members of the staff.

8090. *INFORMAL STUDY IN ENGINEERING PHYSICS.* Either term. Laboratory or theoretical work in any branch of engineering physics under the direction of a member of the staff. Hours to be arranged.

8121. *CLASSICAL THERMODYNAMICS.* Credit three hours. Fall term. Three recitations a week. Primarily for candidates for the degree of Bachelor of Engineering Physics. Introduction to the kinetic theory of gases and brief introduction to statistical mechanics. Application to physical and engineering problems.

8122. *CLASSICAL THERMODYNAMICS.* Credit three hours. Spring term. Three recitations a week. Continuation of 8121.

8512. *ELECTRON MICROSCOPY.* Credit three hours. Spring term. Prerequisite, consent of the instructor. Lectures, M W F 10. Laboratory hours to be arranged. Basic electron optics, image formation and interpretation, construction and operation of the electron microscope in physics, chemistry, and biology. Mr. SIEGEL.

8517. *ELECTRON OPTICS AND ITS APPLICATIONS.* Credit three hours. Fall term. Prerequisites, Physics 225 (Physics 215 advised but not required). M W F 11. Electron beam formation, Gaussian dioptrics and aberrations of electron lenses, application including cathode, ray tube, electron microscope, beta ray spectrometer, mass spectrometer. Mr. SIEGEL.

GENERAL COURSES OF INSTRUCTION

Described in this section are certain courses prescribed for students in engineering, given in the College of Arts and Sciences, the College of Agriculture, or other divisions of the University as indicated below.

MILITARY TRAINING

The University requirement in military training (see p. 15 above and the *Announcement of the Independent Divisions and Departments*) may be satisfied:

(a) by four terms of work in the Department of Military Science and Tactics (Military Science 1, 2 and one of the following pairs: 23, 24; 33, 34; 43, 44; 53, 54; or Military Science 61, 62, 63, 64);

(b) by four terms of work in the Department of Air Science (Air Science 1, 2, 3, 4):

(c) by four terms of work in the Department of Naval Science while registered either as a regular student or as a contract student in the Naval ROTC (Naval Science 101, 102, 201, 202).

Students who have been enrolled in the armed services are exempted from the requirement in military training. A student who is enrolled in the Organized Naval Reserve Program may postpone the military training requirement while he is so enrolled, and the completion of two calendar years of work in the Program shall satisfy the requirement. Any student registered in the Big Red Band may postpone the military training requirement for the term in which he is registered, and any student who satisfactorily completes a term of work in the Big Red Band shall be deemed to have satisfied one term of the University military training requirement.

Advanced courses of two years in military science and tactics and air science are elective and may qualify students for appointments as Second Lieutenants in the Regular Army or Air Force, the Officers Reserve Corps, U.S. Army, or the U.S. Air Force Reserve.

The Department of Naval Science offers a four-year course of training which may qualify students for appointments as Ensigns in the Regular Navy or Naval Reserve or as Second Lieutenants in the Marine Corps or Marine Corps Reserve.

Academic credit of three hours a term may be earned in the advanced courses in military science and tactics and air science. This credit may be applied toward any of the free electives offered in the curricula of the College of Engineering. Students who complete the four-year course in naval science are given University credit for twenty-four hours of college work. At present, net credit toward degree requirements of the various schools of the College of Engineering is as follows: School of Mechanical Engineering, at least 9 hours (Option B, 6 hours); School of Electrical Engineering, 12 hours; School of Chemical and Metallurgical Engineering, 12 hours; School of Civil Engineering, 12 hours; Department of Engineering Physics, 6 hours.

Further details concerning the courses offered in military training may be obtained in the *Announcement of the Independent Divisions and Departments.*

PHYSICAL EDUCATION

The University requirement in physical education (see p. 16 above and the *Announcement of the Independent Divisions and Departments*) may be satisfied by four terms of work in the Department of Physical Education. For this purpose Physical Education 1, 2, 3, and 4 are available to men, and Physical Education 51, 52, 53, and 54, to women. Additional courses in physical education are described in the *Announcement of the Independent Divisions and Departments.*

ARCHITECTURE

REGIONAL AND CITY PLANNING

(In cooperation with the School of Civil Engineering)

Instruction is given by Messrs. DETWEILER, EDMONDSON, MACKESEY, REPS, and WOODBURY.

400, 401. *HISTORY OF ARCHITCTURE.* Throughout the year. Credit three hours a term. A course primarily intended for students who are not architects but who are interested in a brief survey of the history of architecture and its relationship with parallel social, economic, and political trends. No experience in drawing or knowledge of structural elements is required. Either or both terms may be taken for credit.

700. *HISTORY OF CITY PLANNING.* Fall term. Credit three hours. Open to graduates and upperclassmen. The history of the planning of communities from ancient times to the present. Lectures, assigned reading, and examinations.

710. *PRINCIPLES OF CITY AND REGIONAL PLANNING.* Fall term. Credit three hours. Open to graduates and upperclassmen. A review of the basic influences in the development of cities. A general view of the theory and accepted practice of city and regional planning, including a study of the social, economic, and legal phases. Lectures, assigned reading, and examinations.

711. *CITY PLANNING PRACTICE.* Spring term. Credit three hours. Prerequisite, Course 710. The procedures and techniques of gathering and analyzing data for municipal planning studies. The selection and integration of data for use in planning. Practical application of the theories of city planning. Office practice. Lectures, assigned readings, reports.

713. *HOUSING.* Fall term. Credit two hours. Registration limited. Prerequisite, Course 710. An introduction to the theory and standards of housing practice through analysis and comparison of various existing examples, considering the social, economic, and technical sides of the work. Lectures, assigned readings, and reports.

715. *PUBLIC PROBLEMS IN URBAN LAND USE.* Fall term. Credit two hours. Prerequisite, Course 710. Urban land policies, rent, taxation, and market factors.

717. *PLANNING AND ZONING LAW.* Spring term. Credit two hours. Prerequisite, Course 710. Technical and legal aspects of preparing and administering zoning ordinances. Examination of other legal problems in planning, including subdivision control, official map procedure, regulation of roadside development, and building and housing codes.

718. *CITY PLANNING DESIGN.* Fall term. Credit eight hours. Limited to graduate students and, by permission, to seniors who may substitute it for Design 108. Students are assigned a series of design problems as a means of introduction to the basic principles of large-scale site planning. Lectures, discussions, and group and individual criticism.

720. *FIELD PROBLEM IN URBAN PLANNING.* Fall term. Credit eight hours. Group study of an existing community and the preparation of a general plan for its development. Investigation of population trends, economic base, and regional influences. Land use analysis, and studies of traffic flow, recreation facilities, housing conditions, school and public building locations, automobile parking, public transportation and other elements of the community. Preparation of recommendations for carrying out the general plan. Lectures, discussions, field trips, preliminary and final reports.

CHEMISTRY

105-106. *GENERAL CHEMISTRY.* Throughout the year. Credit three hours a term. Chemistry 105 is prerequisite to Chemistry 106. For those students who will take more chemistry, it serves as a prerequisite to the more advanced courses. Open to those who have had or have not had high school chemistry. May be elected by students who do not intend to take more chemistry. Lectures, T Th 9, 10, or 12. Combined discussion-laboratory period, M W F or S 8-11, M T W Th or F 1:40-4:30. Mr. SIENKO, Mr. PLANE and assistants. The important chemical principles and facts will be covered, with considerable attention given to the quantitative aspects and to the techniques which are important for further work in chemistry.

111-112. *INTRODUCTORY INORGANIC CHEMISTRY.* Throughout the year. Credit three hours a term. Chemistry 111 is prerequisite to Chemistry 112. Chemistry 115-116 must be taken with Chemistry 111-112, except by consent of the instructor. Open to those students who have offered high school chemistry for entrance. Required of candidates for the degree of B.Ch.E. and recommended for candidates for the degree of A.B. with a major in chemistry. Lectures, M W F 8. Mr. LAUBENGAYER. A study of the concepts and laws of inorganic chemistry and a systematic treatment of the common elements and their compounds based on atomic structure and the Periodic System.

115-116. *INTRODUCTORY INORGANIC LABORATORY AND QUANTITATIVE ANALYSIS.* Throughout the year. Credit three hours a term. Chemistry 115 is prerequisite to Chemistry 116. Must be taken with Chemistry 111-112. Labortary, T Th 8-11, W F 10-1, or W 1:40-4:30 and S 10-1. Recitation, one hour a week, to be arranged. Mr. LAUBENGAYER, Mr. HEXTER and assistants. The theories of chemistry are applied in a study of the preparation and properties of the common elements and their compounds and to the separation and detection of their ions.

224. *CYTOGENETICS.* Spring term. Credit three hours. Prerequisites, Botany 124 and Genetics 101 or their equivalent. Mr. RANDOLPH. An advanced course dealing mainly with the chromosome mechanism of heredity and with recent researches in cytology, cytotaxonomy, and cytogenetics.

301. *INTRODUCTION TO ORGANIC CHEMISTRY.* Fall term. Credit two hours. Prerequisite, Chemistry 106. For students in engineering. Lectures, W F 9. Mr. BLOMQUIST. A brief survey of the principal classes of organic compounds, their industrial sources, manufacture, and utilization.

307-308. *INTRODUCTORY ORGANIC CHEMISTRY.* Throughout the year. Credit three hours a term. Prerequisite, Chemistry 106 or 112. Qualitative analysis is desirable but not required. Chemistry 307 is prerequisite to Chemistry 308. Chemistry 311-312 must be taken with Chemistry 307-308. Required of candidates for the degrees of B.Ch.E. and A.B. with a major in chemistry. Lectures, M W F 9. Mr. JOHNSON. A systematic study of the more important compounds of carbon, their occurrence, methods of synthesis, relations, and uses.

311-312. *INTRODUCTORY ORGANIC LABORATORY.* Throughout the year. Credit two hours a term. Chemistry 311 is prerequisite to Chemistry 312. Must be taken with Chemistry 307-308. Required of candidates for the degrees of B.Ch.E. and A.B. with a major in chemistry. Laboratory, T Th 1:40-4:30 or F 1:40-4:30 and S 9-12 (either term) or T Th 9-12 (fall term only). Mr. BLOMQUIST, Mr. MEINWALD, and assistants. The student prepares typical compounds of carbon and familiarizes himself with the properties, reactions, and relations.

402. *INTRODUCTION TO PHYSICAL CHEMISTRY.* Spring term. Credit two hours. Prerequisite, Chemistry 106. Prerequisite or parallel courses, Mathematics 163 or 193 and Physics 117. For students in civil and mechanical engineering. Lectures, W F 9. An additional recitation period will be arranged for engineering physics students and others who wish to obtain three hours credit for the course. Mr. BAUER and assistants. A brief survey of physical chemistry. Problems of interest to students in engineering will be discussed.

403-404. *INTRODUCTORY PHYSICAL CHEMISTRY.* Throughout the year. Credit three hours a term. Prerequisite, Chemistry 224 and 308. Mathematics 163 or 193, and Physics 118. Chemistry 403 is prerequisite to Chemistry 404. Required of candidates for the degree of B.Ch.E. Lectures, M W F 9. Mr. SCHERAGA. A systematic treatment of the fundamental principles of physical chemistry. The laws of thermodynamics and of the kinetic theory are applied in a study of the properties of gases, liquids and solids, thermochemistry, properties of solutions, and equilibrium in homogeneous and heterogenous systems. Chemical kinetics and atomic and molecular structure are also studied.

411-412. *INTRODUCTORY PHYSICAL LABORATORY.* Throughout the year. Credit two hours a term. Prerequisite or parallel course, Chemistry 403-404 or 407-408. Chemistry 411 is prerequisite to Chemistry 412. Enrollment may be limited. Required of candidates for the degree of B.Ch.E. and A.B. with a major in chemistry. Laboratory, M T or Th F 2-4:30. Mr. HOARD, Mr. SCHERAGA, and assistants. Quantitative experiments illustrating the principles of physical chemistry, and practice in performing typical physiochemical measurements. A part of the scheduled time is used for the discussion of experiments rather than for laboratory work.

ECONOMICS

107. *INTRODUCTION TO ECONOMICS.* Credit three hours. Either term. Hours to be arranged. For students in engineering. An introduction to the more essential economic features of contemporary American society. Mr. MORSE and assistants.

203. *MONEY, CURRENCY, AND BANKING.* Credit three hours. Fall term. Prerequisite, Economics 106, M W F 11. A study of our currency system and banking processes for the primary purpose of training the student to determine the influence of monetary factors in economic problems. Mr. REED.

ENGLISH

111-112. *INTRODUCTORY COURSE IN READING AND WRITING.* Throughout the year. Credit three hours a term. Open to freshmen, English 111 is prerequisite to 112. M W F 8, 9, 10, 11, 12, 2; T Th S 8, 9, 10, 11, 12. The aim of this course is to increase the student's ability to communicate his own thought and to understand the thought of others. Mr. CRONKHITE and others.

ENGLISH FOR FOREIGNERS

The following two courses are offered by the Division of Modern Languages. Foreign students should consult a member of that division in Morrill Hall 108.

102. *ENGLISH FOR FOREIGNERS.* Fall term. Credit six hours. Prerequisite, placement by the instructor. Hours to be arranged.

211. *ENGLISH FOR FOREIGNERS.* Fall term. Credit six hours. Prerequisite, a satisfactory proficiency examination. Hours to be arranged.

GEOLOGY

113. *ENGINEERING GEOLOGY.* Credit three hours. Either term. Students who have had Geology 101-102 or 115 may take 113 for one hour credit. Lectures, M W 11; spring term, T Th 9. Laboratory, M W or T Th 2-4:30. The purpose of the course is to provide a geologic background so that the engineer will be competent to adapt his work to conform with the limitations imposed by geologic conditions. Mr. ANDERSON.

712. *METALLURGICAL RAW MATERIALS.* Credit three hours. Fall term. For second year students in metallurgical engineering. Lectures, M T Th 9. The properties, occurrence, associations, distribution, and economic aspects of the commercially important ore, refractory, and fluxing materials that enter metallurgical operations. Mr. ANDERSON.

HISTORY

165-166. *SCIENCE IN WESTERN CIVILIZATION.* Credit three hours a term. Throughout the year. A survey of the development of science in its relation to European and American civilization. Primarily for engineers and science majors, but open to other qualified upperclassmen. M W F 11. Mr. BEALE.

INDUSTRIAL AND LABOR RELATIONS

293. *SURVEY OF INDUSTRIAL AND LABOR RELATIONS.* Credit three hours. Either term. A survey for students not in the School of Industrial & Labor Relations. An analysis of the major problems in industrial and labor relations: labor union history, organization, and operation; labor market analysis and employment practices; industrial and labor legislation and social security; personnel management and human relations in industry; collective bargaining; mediation and arbitration; the rights and responsibilities of employers and employees; the major governmental agencies concerned with industrial and labor relations.

MATHEMATICS

161. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit three hours. Prerequisite, trigonometry and intermediate algebra. Hours to be arranged. Plane analytic geometry through conics. Differentiation and integration of polynomials with applications to rates, maxima, volumes, pressures, etc.

Courses 161-162-163 represent a standard three-term calculus sequence, presenting the main ideas and techniques of the calculus and analytic geometry; the material is so arranged that the first two terms (161-162) provide a reasonably complete introduction to the subject. This sequence of courses is not intended as preparatory to more advanced courses in mathematics, although admission to such courses can be obtained following this sequence by special permission. (For students who took the 161-162-163 sequence when it was the only one offered, this will continue to serve as the prerequisite to advanced work.) Students majoring in mathematics or in those physical sciences where mathematics is extensively used or who have special mathematical competence should elect the 181-182-183 sequence instead.

162. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit three hours. Prerequisite, Mathematics 161. Hours to be arranged. Differentiation and integration of algebraic, trigonometric, logarithmic, and exponential functions, with applications. Related topics, including polar coordinates, parametric equations, and vectors.

163. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit three hours. Prerequisite, Mathematics 162. Hours to be arranged. Infinite series, solid analytic geometry, partial derivatives, and multiple integrals.

181. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit three hours. Prerequisite, trigonometry and intermediate algebra. Hours to be arranged. The range of topics will be similar to that of Mathematics 161, but each will be covered more intensively. Intended primarily for students of superior mathematical ability. (See remarks under Mathematics 161 above.)

182. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit three hours. Prerequisite, Mathematics 181. Hours to be arranged.
Topics similar to those of Mathematics 162.

183. *ANALYTIC GEOMETRY AND CALCULUS.* Either term. Credit three hours. Prerequisite, Mathematics 182. Hours to be arranged.
Topics similar to those of Mathematics 163.

201. *ELEMENTARY DIFFERENTIAL EQUATIONS.* Either term. Credit three hours. Prerequisite, Mathematics 163. Fall term, M W F 8, T Th S 11. Spring term, M W F 12, 2, T Th S 10. Solution of ordinary differential equations by analytic and numerical methods.

611-612. *HIGHER CALCULUS.* Throughout the year. Credit three hours a term. Prerequisite, Mathematics 201. First term prerequisite to second. T Th S 10, M W F 8. Primarily for undergraduates. Partial differentiation, multiple and line integrals, Fourier series, partial differential equations, vector analysis, complex variables, calculus of variations, Laplace transforms. Emphasis is placed on a wide range of formal applications of the calculus, rather than on the logical development. The second term will be accepted as prerequisite to complex variables.

613-614. *METHODS OF APPLIED MATHEMATICS.* Throughout the year. Credit three hours a term. Prerequisite, Mathematics 201. T Th S 10. Mr. KAC. Primarily for undergraduates. The first two terms of a proposed four-term course, intended for students who wish to go beyond Mathematics 611-612. Topics to be covered are vector analysis, calculus of functions of several variables, infinite series, and introduction to complex variables. Fourier series and integrals, Laplace transforms. It is expected that the succeeding course, Mathematics 614-615, will cover complex variable theory, partial differential equations, special functions, calculus of variations, matrix theory. Also, Mathematics 613-614 will be a good preparation for Mathematics 621-622.

621-622. *MATHEMATICAL METHODS IN PHYSICS.* Throughout the year. Credit four hours a term. Prerequisites, a good knowledge of the techniques of the calculus, such as given by 611-612 or 613-614, and at least two years of general physics. First term prerequisite to second. T W Th F 12. Mr. FUCHS. For graduate students and qualified undergraduates. Lectures and problem work designed to give the students a working knowledge of the principal mathematical methods used in advanced physics.

PHYSICS

113. *ELECTRICITY AND MAGNETISM.* Fall term. Credit two hours. Prerequisite, Physics 115, 116, calculus or simultaneous registration in Mathematics 163. Lecture Th 10, one recitation and one discussion period a week to be arranged and one laboratory period of 2½ hours on alternate weeks to be arranged. For students of civil engineering only. Mr. NEWHALL and assistants. Survey of the fundamental laws of electric and magnetic fields, electric circuits, induced emfs, inductance, and capacitance. The laboratory experiments are illustrative of the topics mentioned.

114. *PHYSICAL OPTICS AND ATOMIC PHYSICS.* Spring term. Credit two hours. Prerequisite, Physics 113. Lecture Th 10, one recitation and one discussion period a week to be arranged, and one laboratory period of 2½ hours on alternate weeks to be arranged. For students of civil engineering only. Mr. NEWHALL and assistants. Survey of electromagnetic waves and their applications to optical phenomena. Survey of selected topics in atomic and nuclear physics, electronic emission, and photoelectricity. The laboratory experiments are illustrative of the topics mentioned.

Note: Physics 115, 116, 117, and 118 form a sequence in a two-year continuous course in General Physics required of all students of engineering who are candidates for the degree of B.Ch.E., B.E.E., B.Eng.Phys., and B.M.E. Physics 115, 116, 113, and 114 constitute the corresponding sequence for candidates for the degree B.C.E. Demonstrations, theory, experiments, and problem drill. One lecture, two recitations, and one laboratory period a week, as assigned. Consult instructor in charge for available recitation and laboratory periods other than the ones described below.

115. *MECHANICS.* Fall term. Credit three hours. Prerequisite, calculus or simultaneous registration in Mathematics 161. Entrance physics is desirable but not required. Lecture, Th 9 or 11. Recitations, M F 9. Laboratory, M 2-4:30. Mr. GRANTHAM and assistants. Kinetics, statics, elasticity, liquids, and mechanics of gases. The laboratory work consists of measurements related to the above topics.

116. *HEAT, SOUND, AND GEOMETRICAL OPTICS.* Spring term. Credit three hours. Prerequisites, Physics 115, calculus, or simultaneous registration in Mathematics 162. Lecture, Th 9 or 11. Recitations, M F 9. Laboratory, M 2-4:30. Mr. GRANTHAM and assistants. Temperature, calorimetry, change of state, heat transfer, thermal properties of matter, elementary thermodynamics, wave motion, vibrating bodies, acoustical phenomena, geometrical optics, reflection, refraction, mirrors, and lenses. The laboratory work consists of measurements related to the above topics.

117. *ELECTRICITY AND MAGNETISM.* Fall term. Credit three hours. Prerequisites, Physics 115, 116, calculus, or simultaneous registration in Mathematics 163. Lecture, T 8 or 11. Recitations, T Th 10. Laboratory, M 2-4:30. Mr. TOMBOULIAN and assistants. Introductory study of the fundamental laws of electric and magnetic fields and their applications to elementary circuit problems. Electrostatic fields and potential; steady currents, induced emfs, inductance, dielectrics, capacitance, and simple transients. The laboratory work consists of basic measurements in direct current circuits.

118. *PHYSICAL OPTICS AND ATOMIC PHYSICS.* Spring term. Credit three hours. Prerequisite, Physics 117. Lecture, T 8 or 11. Recitations, T Th 10. Laboratory, M 2-4:30. Mr. TOMBOULIAN and assistants. Properties of electromagnetic waves and their application to optical phenomena; interference, diffraction, and polarization. Selected topics in atomic and nuclear physics; spectra, electron emission processes, radioactivity, and nuclear reactions. The laboratory work consists of basic experiments in physical electronics and physical optics.

208. *PHYSICAL MECHANICS AND PROPERTIES OF MATTER.* Spring term. Credit three hours. Prerequisites, Physics 115 and Mathematics 161 and 162. Primarily for candidates for the degree of Bachelor of Engineering Physics. M W F 11. Mr. HARTMAN. Elements of kinematics; Newton's law; conservation laws; D'Alembert's principle; application to selected problems; hydrostatics; elementary fluid dynamics; viscosity.

210. *ADVANCED LABORATORY.* Either term. Credit three hours a term.

Prerequisites, Physics 205 and 206 or the equivalent. Required for physics majors. Laboratory, T W or Th F 1:40-4:30. Messrs. PARRATT, CORSON, CUYKENDALL, DEWIRE, GREISEN, HARTMAN, JOSSEM, SILVERMAN, SPROULL, and WOODWARD. About sixty different experiments are available among the subjects of mechanics, acoustics, optics, spectroscopy, electrical circuits, electronics and ionics, heat, X-rays, crystal structure, solid state, cosmic rays, and nuclear physics. During the term the student is expected to perform five to ten experiments, selected to meet his individual needs. Stress is laid on independent work on the part of the student.

214. *ATOM, NUCLEAR, AND ELECTRON PHYSICS.* Spring term. Credit three hours. Two lectures and one recitation. Prerequisites, Physics 118 and Mathematics 607 or the equivalents. Primarily for students in electrical engineering. Two lectures and one recitation hour to be arranged. Mr. SPROULL. Elements of nuclear and atomic structure, fundamentals of quantum theory, basic kinetic theory of atoms and electrons; electronic processes with special reference to the electrical properties of metals, semiconductors, and insulators and general electron emission processes; elements of nuclear processes.

225. *ELECTRICITY AND MAGNETISM.* Fall term. Credit three hours. Prerequisite, Physics 117 or 204. Lectures, T Th S 9, and an optional problem period to be arranged. Mr. CORSON. Electrostatic and electromagnetic fields, polarization of dielectrics and magnetic media, displacement current, plane electromagnetic waves, the Poynting vector.

236. *ELECTRICITY AND MAGNETISM.* Spring term. Credit three hours. Prerequisites, Physics 225 and differential equations. Lectures, M W F 11. Mr. COCCONI. Circuit theory from the standpoint of electromagnetic fields. Validity and limitation of circuit concepts. Steady and alternating currents in circuits and networks, distributed parameters, introductory high-frequency topics, high-energy machines.

242. *ANALYTICAL MECHANICS.* Spring term. Credit three hours. Prerequisites, Physics 203 and 208 and Mathematics 201, or their equivalents. T Th S 9 and an optional period to be arranged. Mr. WOODWARD. Analytical mechanics of material particles, systems of particles and rigid bodies; planetary motion, stability of orbits; collisions; Euler's equations, gyroscopic motion; Lagrange's equations.

243. *ATOMIC AND MOLECULAR PHYSICS.* Fall term. Credit three hours. Prerequisite, Physics 225, or consent of the instructor. M W F 10. Mr. DEWIRE. The fundamental particles; statistical physics; the concepts of quantum mechanics; atomic structure and spectra; the periodic table; molecular structure and the chemical bond.

254. *ELECTRONIC PROPERTIES OF SOLIDS AND LIQUIDS.* Spring term. Credit three hours. Prerequisite, Physics 243. M W F 9. Mr. SACK. Lattice structure; specific heat; lattice energy; elastic properties; electric conduction; thermoelectric effects; contact potential; barrier effect; lattice defects; dielectric; magnetic and optical properties.

258. *MECHANICS OF CONTINUA.* Spring term. Credit three hours. Prerequisite, partial differential equations or consent of the instructor. Hours to be arranged. Mr. SACK. Equations of state for gases, liquids, solids. Stress-strain relations for continuous media and equations of motion. Special topics in statics of elastic media. Waves and oscillations in continuous media. Topics in flow, and nonlinear phenomena in gases and fluids.

475. *THEORETICAL MECHANICS.* Fall term. Credit three hours. Prerequisite, Physics 242 or its equivalent. T Th S 11. Mr. SALPETER.

PSYCHOLOGY

101. *INTRODUCTION TO PSYCHOLOGY.* Either term. Credit three hours. Open to freshmen. Two lectures plus either a third lecture or a recitation section each week, as announced. Fall term: lectures (M) W F 10; recitation M 9, 10, 12, T 12, 2, or 3; lectures (M) W F 11; recitation M 12, 2, 3, T 12, 2, or 3; lectures T Th (S) 9; recitation, M 2, 3, F 12, 2, S 9, or 10; lectures T Th (S) 11; recitation, M 9, 10, F 12, 2, S 9, or 10. Spring term: lectures (M) W F 10; recitation M 9, 11, 12, 2, T 10, or 11; lectures (M) W F 12; recitation M 9, 11, 12, 2, T 10, or 11; lectures M W (F) 2; recitation Th 12, F 12, 2, S 9, 10, or 11. An introduction to the scientific study of behavior and experience, covering such topics as perception, motivation, emotion, learning, thinking, personality, and individual differences. This course is prerequisite to further work in the Department.

PUBLIC SPEAKING

101. *PUBLIC SPEAKING.* Either term. Credit three hours. Not open to freshmen. M W F 8, 9, 10, 11, 12, or 2; T Th S 8, 9, 10 or 11. Messrs. ARNOLD, WICHELNS, WILSON, and assistants. This course is designed to help the student express his convictions clearly and effectively in oral discourse. Study of basic principles of expository and persuasive speaking with emphasis on selection, evaluation, and organization of materials, and on simplicity and directness of style and delivery. Practice in preparation and delivery of speeches on current issues, in reading aloud, and in chairmanship; study of examples; conferences. Foreign students and others whose pronunciation of English falls below the normal standard, and students with special vocal problems, are advised to confer with Mr. THOMAS or Mr. R. W. ALBRIGHT before registering.